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Water Works Revenue and Expenditure

By Charles H. Capen

A paper presented on May 5, 1948, at the Annual Conference, Atlantic City, N.J., by Charles H. Capen, Chief Engr., North Jersey Dist., Water Supply Commission, Wanaque, N.J.

WHEN any person or group decides to operate on a budget, or to anticipate its needs for the year, it becomes desirable, and usually essential, to scrutinize carefully both income and expenditures. Most water works men have gone through such a procedure at some time or other—even annually, perhaps—but frequently without much success in improving finances.

It is only natural that any desire to change financial procedures, particularly general policies and rates to be charged, will be materially strengthened by a comparison with other water supplies of a similar type or size. There is, of course, the risk of drawing conclusions from cases that are not parallel, if caution is not employed.

The purpose of this paper is to summarize certain data on the principal items of water supply income and outgo, as well as to point out what may be expected, or what should be planned, for the future. In other words, it is hoped that the lessons of the past may be brought to mind and so crystallized that important decisions, particularly about financial policies, may be based on fact rather than fancy.

Anyone who has read the past history of water works, particularly the book of Frontinus by Clemens Herschel, cannot help being impressed by the fact that the water problems of today were in a large measure antedated by more than 2,000 years. Two of the greatest difficulties of ancient days were to obtain adequate compensation from various consumers and to account for a reasonable portion of the water produced. It seems safe to believe that the water works man of today can hardly present any two problems that occupy more time than these.

The lessons of the Roman Empire were lost to a large extent in succeeding years. When water supplies began to flourish in this country, particularly during the latter half of the last century, the profligate use of water was an outgrowth of its great abundance. An examination of records of conservation reveals that metering received its greatest impetus shortly after the turn of the century. In those days it was not uncommon to find that, even with complete metering, the water accounted for was often 70 to 75 per cent or less of the water delivered to the mains.

Today this figure has, on the average, been raised considerably.

With most supplies metered, and waste being gradually reduced, the water works man has only one broad avenue of approach to the ultimate goal of assuring a reasonably certain future. That is by carefully studying all the relative facts involved and attempting thereby to establish a firm financial structure. Frequently the head of the water department is able to convince himself and his associates of the necessity of making some changes in operation or policy (particularly as it may affect either the physical plant or finances or both) but is unable to convince those who ultimately control the purse strings.

With the uninhibited use of water originally induced by lack of meters, especially as experienced in the last half of the nineteenth century, it was particularly essential that supplies should be relatively plentiful. It must be remembered that many of the refinements of quality which are now considered imperative were not then existent, and production costs were correspondingly lower. On the other hand, the multiple-bathroom house, automatically heated homes that encourage frequent bathing, washing machines and many other water-using devices were relatively few, so that the probability of high usage in households was not great.

Unlimited use by industry forced water purveyors to meter large consumers, but immediately brought about sliding or stepped rates. In the days of ample supply, the tendency was toward maximum concessions to industry. Even after the handwriting on the wall clearly showed the necessity for ultimate conservation, many unsound contracts were made. This was particularly true of the early 1930's when any straw was grasped to augment income. One very large corporation, upon making overtures to a city leading toward the establishment of a branch plant there, obtained a contract for water at approximately the bare cost of production. The contract is still in effect but costs have risen so that water is actually being sold at a loss. That is hardly good business.

G. B. Schunke (1) has advocated a uniform fixed rate for all users. New York City has practiced this policy for years for all metered customers. One

TABLE 1

Sources of Revenue, 1947

(Five New Jersey Cities)

Source of Revenue	Revenue—*per cent*					
	A	*B*	*C*	*D*	*E*	Avg.
Metered private services	77.5	85.3	97.7	78.4	80.4	83.9
Unmetered private services	1.1					0.2
Services to other systems	18.5	11.7		15.3	17.1	12.5
Municipal hydrant services				5.4	2.5	1.6
Other municipal services	0.7	2.8		0.9		0.9
Total water sales	97.8	99.8	97.7	100.0	100.0	99.1
Miscellaneous revenue	2.2	0.2	2.3	0	0	0.9
Total operating revenue	100.0	100.0	100.0	100.0	100.0	100.0

municipality in New Jersey which had such a fixed rate lost a large industry that was exploring the possibility of establishing a plant there, chiefly because of the high water rate. The industry was located not far away and soon spent large sums to secure an adequate water supply. Its demands now exceed what was then the margin of available water for the municipality.

In compiling data for illustrating the facts brought forth in this paper, two principal sources of information have been used. One is the reports filed by all the water supplies in New Jersey with the New Jersey Board of Public Utility Commissioners. The other is the "Survey of Operating Data for Water Works in 1945" published in the JOURNAL as an A.W.W.A. report (2). The first group has been used very largely to find the long-term trend in expenses and revenues. The second has supplied up-to-date results from representative American cities.

Sources of Revenue

Surprisingly often it is difficult to obtain the breakdown of sources from which water revenue is received. Table 1 shows the figures available for five of the larger publicly owned supplies in New Jersey, arranged in order of gross revenue, *A* being the largest of these. (If arranged in order of water produced, *C* would be in position *E*, and *D* and *E* would each advance one place.) The sources of these five supplies are:

A—gravity, unfiltered surface supply
B—gravity, unfiltered surface supply
C—pumped well water
D—pumped well water, filtered for iron removal
E—pumped surface water, filtered.

TABLE 2
Sources of Revenue, 1947
(Five New Jersey Water Companies)

Source of Revenue	Revenue—*per cent*					
	F	*G*	*H*	*I*	*J**	Avg.
Metered private services	87.2	76.2	86.2	75.0	80.7	81.1
Unmetered private services			0.6	0.1		0.1
Services to other systems	0.1	8.3	2.0	1.7	7.8	4.0
Municipal hydrant services	12.5	11.4	10.9	21.3	11.2	13.5
Other municipal services		4.1		1.4		1.1
Miscellaneous water service				0.5	0.1	0.1
Total water sales	99.8	100.0	99.7	100.0	99.8	99.9
Miscellaneous revenue	0.2	0	0.3	0	0.2	0.1
Total operating revenue	100.0	100.0	100.0	100.0	100.0	100.0

* 1946.

Supply *C* serves a large residential city with few industries. Its revenues and costs are somewhat unusual.

The significant feature of Table 1 is that it represents the principal revenue breakdown found in New Jersey reports for these particular cities. It is important to note that if service to other systems (that is, wholesale transactions with other municipalities) is eliminated, the great bulk of water is actually sold to metered customers—including both industrial and domestic services—for which no percentage

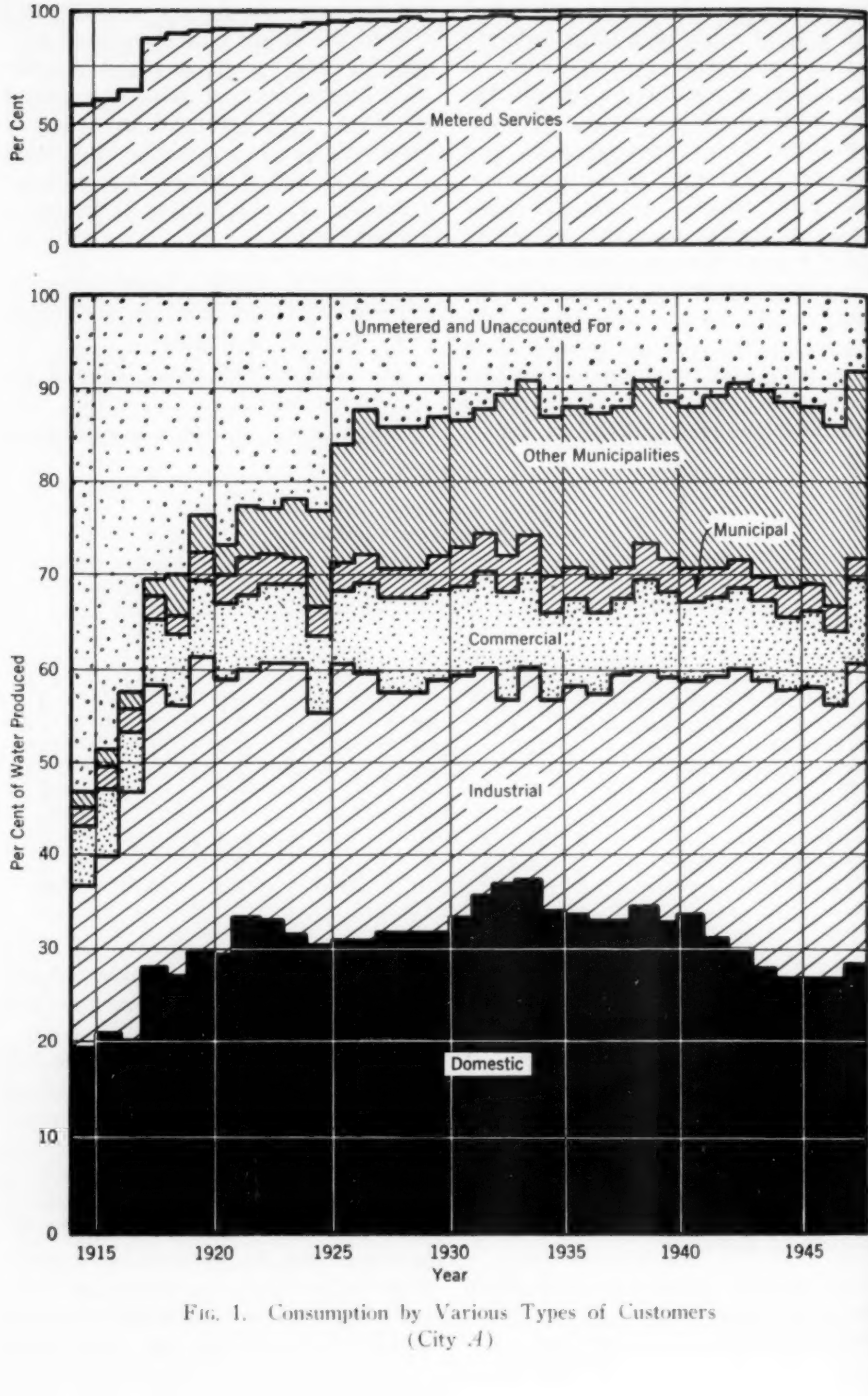

FIG. 1. Consumption by Various Types of Customers (City *A*)

breakdown is readily available from this group.

As an indication, however, of the actual use of water in one of these cities by the several different categories of customers, Fig. 1 shows the breakdown for City *A* of Table 1. This consumption cannot, of course, be accurately divided into dollar value because of variations in the rates charged to the several classes of customers. Some important deductions can be gained, however, by a study of Fig. 1. Domestic use has been reasonably stable during the 30 years of record since the system became largely metered, except for the depression era in the 1930's, when, as expected, other uses decreased and household use correspondingly constituted a greater portion of the whole. Industrial use of water reached a low in 1933 and has subsequently increased to its highest peak in history. Commercial and office use, as well as that by schools, hospitals and churches, has been fairly constant. Unmetered and unaccounted-for water has become largely stabilized in the last 20 years.

As a further comparison, residential revenue for 1945 for City *A* totalled 34.2 per cent of the gross revenue, though accounting for only 26.6 per cent of the consumption. Industrial and commercial uses together yielded 44.6 per cent of the revenue for 39.6 per cent of use.

Table 2 shows the same data as in Table 1 for five large private water companies in New Jersey. These are also arranged in order of gross revenue, *F* being the largest.

The principal difference between Tables 1 and 2 is in the services to other systems and municipal hydrant services. For publicly owned supplies, the former are large and the latter small, while the reverse is true of private water companies.

TABLE 3

Breakdown of Revenue by Type of Customer, 1945

(U.S. Cities)

Class of City	No. of Cities	Revenue—*per cent*				
		Type of Customer			Total	Balance From Other Sources
		Residential	Commercial	Industrial		
1	2	46.3	26.6	9.2	82.1	17.9
2	13	50.3	20.0	16.7	87.0	13.0
3	16	55.4	19.9	16.2	91.5	8.5
4	55	49.4	15.4	23.9	88.7	11.3
5	46	53.1	15.5	23.1	91.7	8.3

In correlating the information contained in the A.W.W.A. report (2), the cities were divided into five classes:

Class	Population Range
1	Over 1,000,000
2	250,000 to 1,000,000
3	100,000 to 250,000
4	25,000 to 100,000
5	Under 25,000

This grouping follows an arrangement used by others as well as the author and thereby affords an opportunity for comparison.

All cities in the respective classes were marked in the tabulation and then summaries were made of those columns

in which analogous or comparable figures were available. Totals of the various columns were made for each and an average or ratio was then calculated from the respective sums. This method, of course, gives a weighted average, but spot checks show that, on the whole, the results are not far different from those that would be obtained if individual comparisons were made and then summarized.

Table 3 shows the per cent of total revenue received from residential, commercial and industrial users by the five classes of cities.

This table, while not entirely consistent, shows certain general trends. The percentage of total revenue obtained from residential and industrial users tends to increase as the size of the city decreases; the percentage from commercial and other sources tends to decrease as the size of the city decreases.

An interesting point to be noted is that the sum of the commercial and industrial revenue percentages is very nearly constant for all classes of cities, the variation lying between the limits of 35.8 and 39.3 per cent of the total. This indicates that as a city grows, commercial revenue becomes increasingly important, while industrial revenue becomes less so. It would be well to take this fact into consideration when establishing rates, particularly in a rapidly growing community.

It is evident from the operating data survey that municipal and fire revenues vary so widely that no definite trend can be found. A noteworthy point about miscellaneous revenue is that large cities in general have a rather high percentage of income in this category. This is believed to be brought about by the substantial sales to other cities or systems.

Although many cities have not supplied a breakdown of the sources of revenue, most have reported total revenue. The figures in Table 4 represent a large proportion of the 462 cities included in the A.W.W.A. report. The book value and funded debt statistics in Table 4 are expressed in terms of dollars per million gallons produced. This unit is preferred to dollars per consumer because in larger cities the custom of serving outside communities gives an unbalanced comparison when one connection may be reported for several thousand actual users.

Table 4 illustrates clearly the frequently noted condition in which the revenue per million gallons is less for large cities than for smaller ones. In the range of the larger cities these re-

TABLE 4

Ratio of Revenue and Funded Debt to Book Value, 1945

(U.S. Cities)

Class of City	Book Value \$/mil.gal.	Revenue		Funded Debt	
		\$/mil.gal.	Per Cent of Book Value	\$/mil.gal.	Per Cent of Book Value
1	1,180	86	7.3	665	56.3
2	1,390	131	9.4	515	37.4
3	1,160	130	11.2	380	32.8
4	1,110	121	10.9	320	28.9
5	1,280	136	10.6	365	28.5

sults correspond reasonably well with those given by Capen (3) in 1937, but give considerably lower values for smaller cities. This is believed to be attributable, at least in part, to the spreading of industry to the smaller cities and the corresponding sale of water at lower rates.

The book value appears to be fairly stable, but the ratio of revenue to book value is unmistakably lower for larger cities. The funded debt decreases materially with a decrease in the size of the city. It appears that large cities must have had to expand their facilities considerably within the past two or three decades, while smaller cities probably have not done so to such a great degree. The correspondingly lower ratio of funded debt to book value for the smaller cities is likewise noteworthy.

Expenditures

To illustrate the general trends most effectively it has been necessary to follow the financial fortunes of the five New Jersey cities previously mentioned over a period of nearly 35 years. Figure 2 shows the average operating expense, amortization and taxes for this group. The sum of these items, also shown, represents total revenue deductions, all figures being given as a per cent of gross revenue (or cents per dollar revenue).

Figure 3 illustrates the division of the balance between total revenue deductions and gross revenue, generally known as gross corporate income. The important lesson to be learned from these figures is that the ratio of operating expense to gross revenue has gradually increased.

This same picture, in terms of dollars per million gallons produced—rather than in per cent of revenue—is given in Table 5.

It should be noted that in New Jersey the method of accounting prescribed for utilities normally includes

TABLE 5

Operating Expense and Gross Revenue
(Five N.J. Cities)

Year	Item	City A	City B	City C	City D	City E	Avg.
		$/mil.gal.					
1913	Operating expense	19	14	58	22	22	27
	Gross revenue	87	82	184	65	86	101
1928	Operating expense	50	41	92	73	75	66
	Gross revenue	104	101	204	158	124	138
1947	Operating expense	54	42	135	62	64	71
	General amortization	22	16	34	19	19	22
	Taxes	3	2	14	1	0.4	4
	Revenue deductions	79	60	183	82	83	97
	Gross revenue	123	120	192	133	122	138
	Operating expense—per cent of gross revenue	44	35	70	47	53	51.5

general amortization as part of operating expenses. In Table 5 these two have been separated in order to provide a comparison with figures from the A.W.W.A. survey. The effect of metering, a large part of which was accomplished in all five cities in the period covered in Table 5, is readily apparent in the increase in revenue per million gallons during the period between 1913 and 1928. Rate increases since then have been offset by the demand of neighboring communities for more water at wholesale, so that the average gross revenue per million gallons was the same in 1947 as in 1928.

Operating expenses per million gallons for water utilities in the United States are given in Table 6. The five New Jersey cities, though not all confined to one population class, fall, on the average, in Class 3. The average 1947 operating costs for the five cities are given as $71 per million gallons in Table 5, while the figure for Class 3 cities in Table 6 is $56. The latter table is, however, based on figures for 1945. For that year the New Jersey

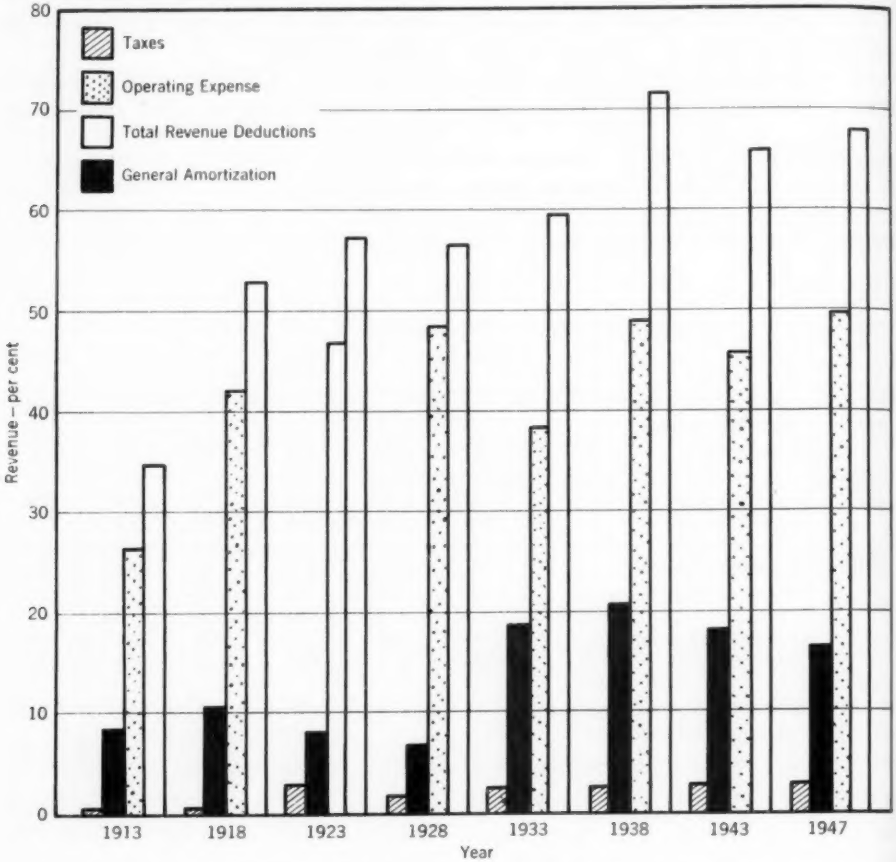

FIG. 2. Ratio of Expense to Revenue * (Five N.J. Cities)

* Total revenue deductions include taxes, operating expense and general amortization.

cities show more nearly the same results as in Table 6. If city *C* (previously described as unusual) is omitted, the similarity becomes striking.

In order to give a more comprehensive picture of the private water companies, Table 7 and Fig. 4 and 5 show the same data for private utilities as greater for private supplies, but the ratio of operating expense to gross revenue, excepting the item of taxes, differs only slightly. It may be interesting to note that for 1913, 1928 and 1947 the ratio of operating expenses to gross revenue was, respectively, 26, 48 and 50 per cent for the cities, as com-

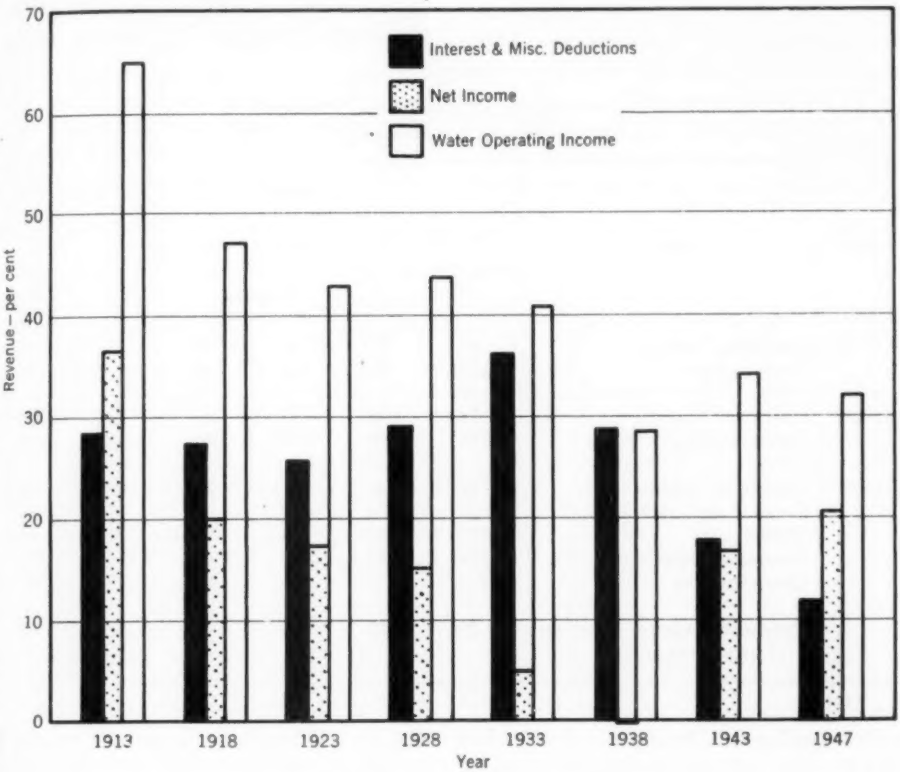

FIG. 3. Ratio of Income to Revenue
(Five N.J. Cities)

Table 5 and Fig. 2 and 3 show for public supplies. In fairness it must be pointed out that these companies serve, generally, the more suburban communities, where there are few large customers and where costs are higher because of the greater dollar investment for each customer. The cost of operation per million gallons is therefore pared with 29, 32 and 37 per cent for the companies.

Table 8 shows the variations in net income per million gallons for New Jersey municipalities from 1913 to 1947. This table is extremely significant. In the period following World War I, the average net income was fairly well stabilized around \$20 per

TABLE 6

Operating Expense, 1945
(U.S. Cities)

Class of City	Expense—$/*mil.gal.*
1	30
2	51
3	56
4	61
5	74

pany in 1933 were omitted, the results in Table 9 would be strikingly stable. This speaks well for the management of the water companies and indicates that municipal utilities might do well to emulate their example.

The significance of Table 9, which shows the funded debt for the five New Jersey cities, is further emphasized by the interest payment data given in Table 11. With these figures in mind, it is possible to appreciate that any large capital expenditure at present will materially reduce net income in spite of low interest rates.

It is obvious from Table 11 that the trend toward debt reduction has been a very important one in the New Jersey area. It must be observed, however, that expansion in production facilities has not been large in these cities within the last fifteen years. Their demand is increasing and may eventually require considerable sums to meet the needs of the consumers. When that happens,

TABLE 7

Operating Expense and Gross Revenue
(Five N.J. Companies)

Year	Item	Company *F*	Company *G*	Company *H*	Company *I*	Company *J*	Avg.
		$/*mil.gal.*					
1913	Operating expense	33	31	46	24	22	31
	Gross revenue	120	85	151	110	68	107
1928	Operating expense	71	95	78	61	72	75
	Gross revenue	250	219	272	251	200	238
1947	Operating expense	87	106	102	96	88*	96
	General amortization	22	13	19	18	17*	18
	Taxes	105	62	74	95	71*	81
	Revenue deductions	214	181	195	209	176*	195
	Gross revenue	296	227	259	292	235*	262
	Operating expense—per cent of gross revenue	29	47	39	33	38*	37

* 1946.

million gallons. During the depression era the net income diminished to zero. It has since returned to the $25 region. In terms of dollar value, however, it is now approximately half of what it was in the period after World War I. When the reduced funded debt (Table 9) is taken into account, the disparity is even more striking.

A similar summary of net income, prepared for the five private water companies is given in Table 10. The important difference between this and Table 8 lies in the greater uniformity of results. If the record of one com-

the annual carrying charges will materially affect interest payments and may even reduce net income to the vanishing point unless rates are increased.

As a further yardstick, Table 12 shows the funded debt and capital stock (per million gallons) for the private companies. Of course, it is customary for such enterprises to maintain a generally increasing obligation although some bonds are occasionally retired. No table has been prepared showing the payments on these obligations, largely because dividends on capital stock are usually determined arbitrarily each year and may not always be useful as a basis for a fair comparison.

Table 13 gives the "water fixed capital" (corresponding somewhat to book value) of the five New Jersey cities.*

It will be noticed that this item increased during the period following World War I but gradually decreased during the last fifteen years. This, of course, reflects the lack of material expansion in facilities since the depression era. When further expansion becomes necessary, it is obvious that at present levels the cost of additions will be so much greater than formerly that net income will be affected in a most drastic manner. The same point has been forcibly stated by Howson (4).

Comparing the 1947 average in Table 13 with the book value given in Table 4, it is found that the New Jersey cities have a somewhat higher capital structure than the corresponding group (Class 3) for the United States, where the figure is $1,125 per million gallons.

Table 14 lists the water fixed capital data for the five private companies. The average of these companies has followed the same general trend as that of the five municipalities. It started at a little lower value per million gallons than the average for the cities, reached a peak in 1933 (due not to large expenditures in the early 1930's but to

TABLE 8

Net Income, 1913–47
(Five N.J. Cities)

Year	City					Avg.
	A	*B*	*C*	*D*	*E*	
	$/mil.gal.					
1913	7	27	47	30	61	34
1918	16	17	33	18	10	19
1923	23	18	−10	16	43	18
1928	18	11	17	26	27	20
1933	−13	15	2	−15	37	5
1938	1	14	10	−33	10	0
1943	21	25	7	20	25	20
1947	26	37	−1	35	29	25

* Throughout the text, the terms "rate base," "book value," "water fixed capital" and "capital" are used almost interchangeably. The same is true of the terms "depreciation" and "amortization." This does not necessarily provide a true concept of the meaning of the terms, but it is impossible always to evaluate their use. Even when regulatory bodies define such terms, and certainly in annual reports, there are frequently various interpretations of their meaning.

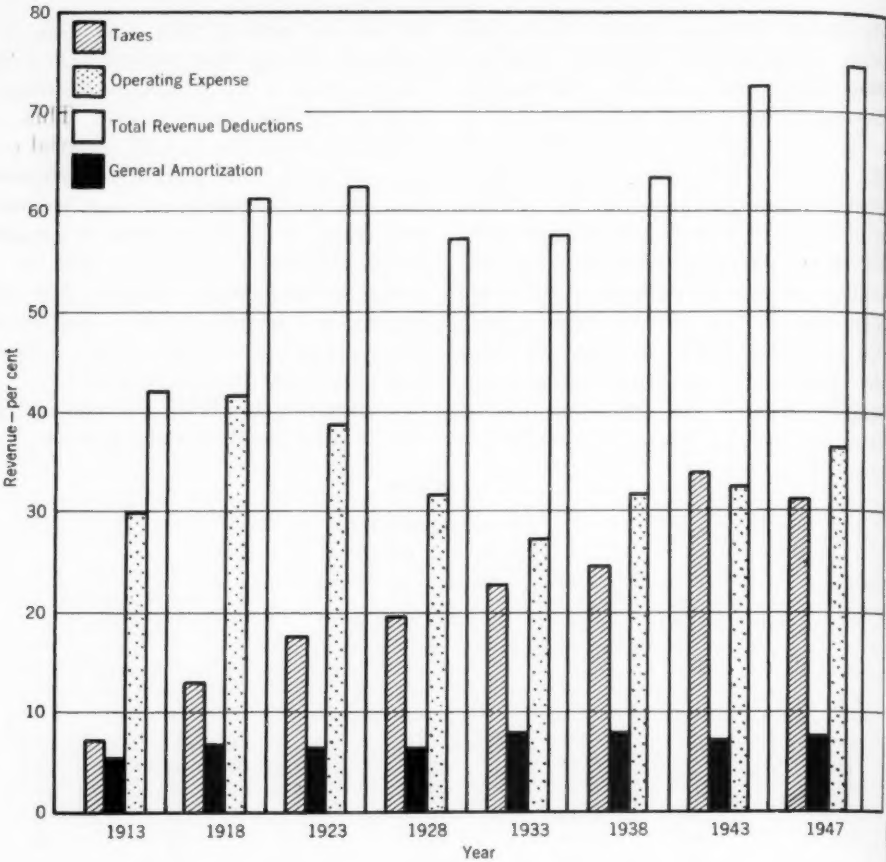

FIG. 4. Ratio of Expense to Revenue* (Five N.J. Companies)

* Total revenue deductions include taxes, operating expense and general amortization.

lower output) and has gradually diminished.

It has been customary for the private companies in New Jersey to apply from time to time for permission to make rate adjustments. Often this calls for a revaluation of the system and frequently the capital structure is increased in a bookkeeping transaction. The cities generally do not follow this practice but they might well consider the advisability of doing so.

Wages and Salaries

During the depression era, industrial cities were hardest hit from the standpoint of water works revenue and expense. It is only natural, therefore, that they were forced to cut salaries and wages to the bone. The best criterion perhaps is not the actual dollars paid in total wages but rather the cost per million gallons. In one of the New Jersey cities studied, this figure has actually decreased between 1933 and 1947, while the average increase is less than 50 per cent.

The water companies, serving more largely residential areas, were able to arrange their financing with sufficient uniformity to maintain a fairly stable remuneration during the early 1930's.

with the result that their wage outlay per million gallons has not increased as much as the publicly owned systems.

The average wage cost per million gallons is now approximately $50 both for publicly and privately owned sources in the cases studied. The figure is much higher in many other instances for good reasons, and no use should be made of the statements presented here without careful consideration of all the factors involved. No comment on this matter would be complete without expressing the warning that water works personnel costs will generally follow the trend of the country at large. If even a portion of the third round of wage increases now being discussed throughout the nation is granted, water income will be affected and eventually a reconsideration of rate structures will be necessary.

Taxes

It is obvious from Fig. 2 and 4 that there is a wide discrepancy between taxes on publicly owned supplies and on private utilities. In the author's opinion, much controversy would be eliminated if publicly owned water works could be made to pay rent, taxes and other charges just as do privately owned systems. Likewise, publicly owned utilities should collect revenue from all users.

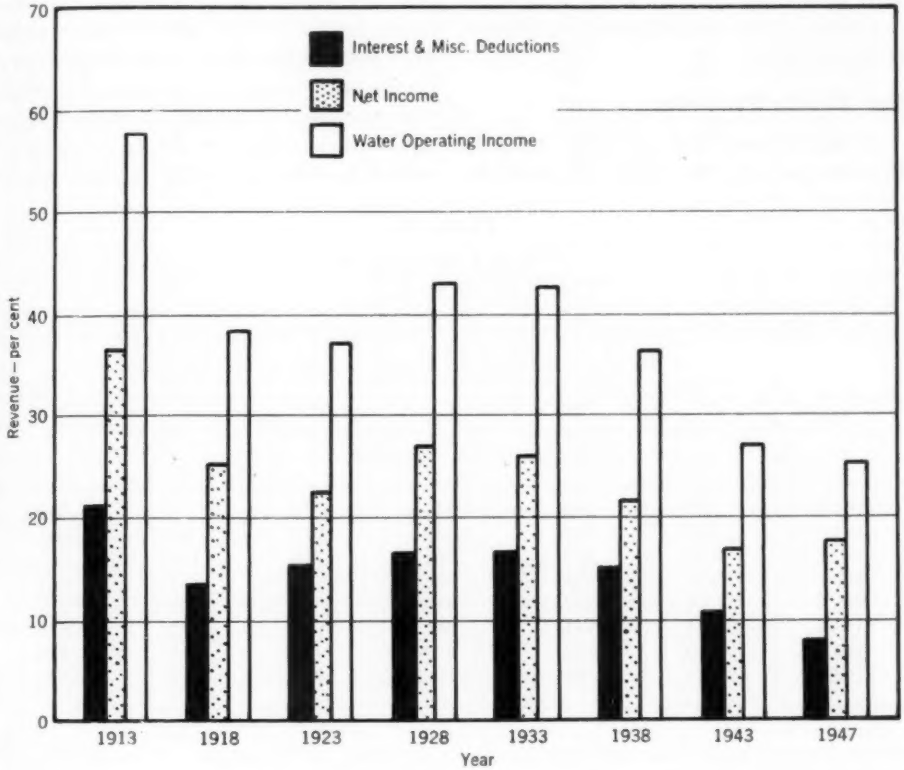

FIG. 5. Ratio of Income to Revenue
(Five N.J. Companies)

On the other hand, the private company cannot be taxed out of existence. Continued increases in taxes will only result in the upward readjustment of rates. When it is observed that, on the average, nearly one-third of all revenue received by the companies in New Jersey is paid out in taxes and that this proportion is double what it was a quarter of a century ago, it is not difficult to visualize the problems lying ahead.

Per Capita Statistics

It was hoped that a fairly comprehensive and reliable tabulation could be made for per capita revenue and costs. Some occasional checks on the populations reported in the 1945 nationwide canvas, however, show clearly that many cities listed only the population served within municipal boundaries. Numerous instances exist where the number of persons served outside city limits constitutes a rather large percentage of all users. Table 15, therefore, is presented with the qualification that it is merely indicative of trends and cannot be relied upon too strongly. These figures show some results that cannot be readily explained. Although it appears that operation and maintenance costs increase as population decreases, the true relationship of such costs is not susceptible of accurate evaluation because of the discrepancy in population figures previously noted.

Perhaps the most inexplicable results are the daily per capita consumption statistics. It is a well-known axiom that small cities show a much lower per capita usage than large ones, for obvious reasons. Tabulations made by the author and others in the past, many of which have been published, have clearly depicted the situation. It would appear that the per capita results given in Table 15 for cities of the first two classes are close to the usually accepted figures. The third is somewhat at variance, while the fourth and fifth classes are distinctly high.

The movement of many small industries, as well as small units of large industries, to decentralized areas has perhaps had a material effect on the per capita consumption in the three latter classes. Another possibility is

TABLE 9

Funded Debt, 1913–47

(Five N.J. Cities)

Year	City					Avg.
	A	*B*	*C*	*D*	*E*	
	$/*mil.gal.*					
1913	890	680	1,140	274	0	598
1918	775	528	1,162	278	80	565
1923	620	742	961	710	194	645
1928	880	838	956	1,155	475	861
1933	1,265	833	446	1,546	501	918
1938	995	741	311	902	442	678
1943	680	562	152	477	311	436
1947	415	501	106	275	318	323

TABLE 10

Net Income, 1913–47
(Five N.J. Companies)

Year	Company					Avg.
	F	*G*	*H*	*I*	*J*	
	$/*mil.gal.*					
1913	50	41	26	56	18	38
1918	28	21	30	48	15	28
1923	62	44	49	29	16	40
1928	46	52	63	112	47	64
1933	67	72	54	143	43	76
1938	68	79	36	106	35	65
1943	51	57	25	71	25	46
1947	58	45	23	66	37	46

that the nation as a whole—with more money in its pockets, with more bathrooms per house and with a constantly increasing demand due to air conditioning and to household appliances for washing clothes or dishes and for garbage disposal—has actually gone on a water binge. There are, of course, innumerable examples of increased use in a large majority of cities throughout the country. Nevertheless it is hard to believe that such increases could be found only in smaller cities. It seems more plausible that the per capita results obtained from Table 15 are by no means accurate, largely because of the lack of reliable information on the population served.

Bearing in mind this same note of caution, Table 16 has been prepared showing further statistical data for the United States as a whole. All of the columns in Table 16 indicate certain trends, the least consistent being the last two. Of primary importance are the data on the rates per 1,000 cu.ft.

TABLE 11

Interest on Funded Debt
(Five N.J. Cities)

Year	City					Avg.
	A	*B*	*C*	*D*	*E*	
	$/*mil.gal.*					
1913	35	30	48	12	0	25
1918	31	23	45	12	4	23
1923	16	36	37	39	9	27
1928	15	39	38	54	22	34
1933	57	40	32	69	23	44
1938	44	36	13	42	20	31
1943	29	27	7	23	14	20
1947	19	23	5	13	9	14

TABLE 12

Funded Debt and Capital Stock

(Five N.J. Companies)

Year	Item	Company F	G	H	I	J	Avg.
		$ /mil.gal.					
1913	Debt	540	98	1,030	241	332	448
	Stock	455	194	690	505	242	417
	Total	995	292	1,720	746	574	865
1918	Debt	406	67	745	303	153	335
	Stock	469	132	695	500	124	384
	Total	875	199	1,440	803	277	719
1923	Debt	580	168	920	330	322	464
	Stock	640	690	570	398	212	502
	Total	1,220	858	1,490	728	534	966
1928	Debt	805	550	950	565	610	696
	Stock	800	650	338	408	218	483
	Total	1,605	1,200	1,288	973	828	1,179
1933	Debt	1,190	124	1,460	530	900	841
	Stock	765	1,260	590	485	450	710
	Total	1,955	1,384	2,050	1,015	1,350	1,551
1938	Debt	1,250	112	1,370	465	800	799
	Stock	800	1,130	560	425	400	663
	Total	2,050	1,242	1,930	890	1,200	1,462
1943	Debt	1,040	21	1,250	570	585	693
	Stock	662	685	690	335	290	532
	Total	1,702	706	1,940	905	875	1,225
1947	Debt	970	19	1,020	480	615	621
	Stock	495	620	560	280	240	439
	Total	1,465	639	1,580	760	855	1,060

Some further consideration of this item seems in order. In 1944, the author made a similar digest (5) of meter rates from data extending over the period 1926 to 1940. A comparison with the 1945 figures shows that rates in large cities are considerably higher than formerly. Part of this difference may be explained by the fact that certain cities having relatively high meter rates have accumulated sufficient growth in population to be advanced to the next class and have had an important influence on average rates. It is also probable that some rate increases have occurred in the interim.

Improved Financing

Having assembled these tables it is desirable to observe what can be done about inconsistent financing. Perhaps the most important step is a study of the rate base. A survey (6) has shown that in the years 1925 to 1947, inclu-

TABLE 13

Water Fixed Capital, 1913–47

(Five N.J. Cities)

Year	City A	City B	City C	City D	City E	Avg.
	$/mil.gal.					
1913	1,360	728	1,320	388	554	870
1918	1,240	624	1,610	452	420	869
1923	1,410	921	1,520	992	618	1,092
1928	1,360	1,010	1,680	1,600	718	1,274
1933	2,560	1,270	1,790	2,350	1,010	1,796
1938	2,240	1,295	1,845	1,980	950	1,662
1943	1,800	1,140	2,000	1,400	805	1,429
1947	1,620	1,080	1,780	1,210	697	1,277

TABLE 14

Water Fixed Capital, 1913–47

(Five N.J. Companies)

Year	Company F	Company G	Company H	Company I	Company J	Avg.
	$/mil.gal.					
1913	1,085	375	800	780	610	730
1918	975	290	1,500	880	370	803
1923	1,530	970	1,820	910	585	1,163
1928	2,100	1,240	1,800	1,250	900	1,458
1933	2,430	1,770	2,260	1,830	1,750	2,008
1938	2,800	1,720	2,260	1,790	1,650	2,044
1943	2,370	1,130	2,310	1,630	1,270	1,742
1947	2,200	1,130	1,970	1,500	1,190	1,598

TABLE 15

Per Capita Statistics, 1945

(U.S. Cities)

Class of City	Book Value	Annual Revenue	Annual Op. & Maint.	Water Consumed, *gpd.*
	per capita			
1	$74	$5.45	$1.91	168
2	66	6.28	2.39	129
3	53	6.00	2.57	125
4	51	5.61	2.88	127
5	58	6.15	3.88	123

sive, water works construction in the United States varied from the low of 1932 (approximately $30,000,000) to a high of nearly $200,000,000 in 1939. Howson (4) has given the average as $120,000,000 over approximately the same period and has pointed out how the decreased purchasing power of the dollar makes it advisable to increase revenue if water systems are to be fully implemented for future demands.

Another approach to this question, and with nearly the same results, is offered by studying the water fixed capital data for the five cities in New Jersey (*see* Table 13). By any rational basis of comparison it is clear that cities cannot continue to operate indefinitely with a lower capital structure per million-gallon output today than that which existed ten years ago. In fact the unit capital is now only equal to that of two decades ago.

If the fixed capital of any city were stepped up artificially by a revaluation of the entire plant on the basis of present-day values and costs (a practice which private companies have had to follow) the unit value per million gallons produced would be considerably higher than that now carried on the books, even after due allowances for depreciation. In examples studied recently by the author, mark-ups may run anywhere from 20 to 50 per cent, or perhaps even higher.

Table 4 shows that revenues in all but the large cities average around 11 per cent of book value. Most cities up to 500,000 population can do fairly well in normal times with 10 per cent or a little more. But were these book values brought up to present-day worth in terms of the purchasing power of the dollar, the estimated ratio of revenue to book value would not be more than 8 per cent. This is not enough to permit the expansion of facilities that is required to meet current and future demands.

A further study of the detailed figures from which statistics of publicly owned supplies in New Jersey have been compiled shows that cities approaching half a million in population may operate on a revenue-to-capital ratio of less than 10 per cent. On the other hand, in a group of small supplies with annual revenues of less than $10,000, even in the flush year of 1929 nearly 35 per cent had operating losses though the revenues represented 10.5 per cent of capital. In 1932 water revenues for this same group dropped to 9.6 per cent of capital, and 41 per cent of the múnicipalities had operating losses.

Presumably the system of public utility accounting existing in New Jersey has been a factor in the care in operating water works on a sound financial basis, regardless of the fact that the

TABLE 16

Additional Data for U.S. Cities, 1945

Class of City	Persons per Connection	Monthly Rates per 1,000 cu.ft.	Mains per 1,000 pop. *mi.*	Valves per Mile of Main	Hydrants per Mile of Main
1	6.7	$1.23	1.64	16.5	9.4
2	5.6	1.69	1.74	14.2	6.8
3	4.7	1.73	2.19	14.4	6.5
4	4.7	1.91	2.64	12.6	6.4
5	4.2	2.16	2.99	12.7	7.0

New Jersey Board of Public Utility Commissioners exercises only a casual jurisdiction over publicly owned supplies. It is apparent that revenues in New Jersey are generally less than elsewhere in terms of ratio to capital. It is not difficult to discern, however, that for the very largest cities a ratio of approximately 7.5 per cent appears to be a minimum, while cities of 10,000 to 25,000 population require 11 per cent. A general average of at least 10 per cent is indicated, calculated on a rational capital value.

It should also be noted that if capital value is increased, amortization should likewise be increased, and this will again have an effect on net income.

TABLE 17

Relation of Revenue, Capital and Net Income

Year	No. of Cities	Ratio of Revenue to Capital *per cent*	Ratio of Net Income to Revenue *per cent*
1913	12	9.9	24.2
1926	102	11.8	16.5
1932	135	8.8	0.9
1936	152	8.9	8.2
1947	5	10.8	18.1

To substantiate the statement that ordinarily the ratio of revenue to capital should not be less than 10 per cent, Table 17 is presented, showing long-term trends for various cities in New Jersey. This table, though not wholly consistent, illustrates clearly how sensitive the ratio of revenue to capital is to general economic conditions. Of course, it is essential to have a reasonably stabilized economy and fixed capital, to establish a rate that will be satisfactory to the customers and yet produce the desired results.

No great difficulty was experienced in the 1913 to 1926 era in financing future extensions. It is most important to note, however, that the funded debt in 1926 was twice that of 1947, but that net income is nevertheless comparable in those two years. When extensions are required at currently inflated costs, the margin of net income may be expected to reduce almost to the vanishing point.

The answer may be found in an increase of the rate base by means of a revaluation and a readjustment of the rates to fit the circumstances.

It may well be argued that much of the 1926 fixed capital was financed

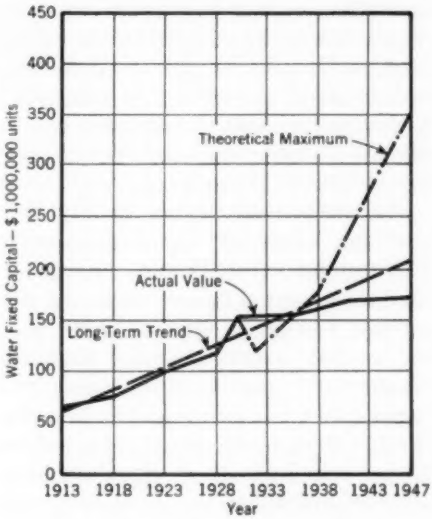

FIG. 6. Water Fixed Capital (100 N.J. Water Works)

prior to 1913 when the cost index was only half of that in the period following World War I, just as the cost index has now more than doubled over 1926. The funded debt in 1926 was, however, well above 1913 levels but by sharp contrast the funded debt in 1947 is less than half of 1926. A study of the tables shows that some $20 per million gallons may be allocated to additional requirements for funded debt payments if improvements are made on a dollar purchasing scale equivalent to that of

1926. If construction costs are considered to have gone up 125 per cent, a total of $45 per million gallons would now be required. Actually interest rates are considerably lower, and, to get a true perspective, a careful calculation of balance is needed. An estimated $35 increase in revenue per million gallons appears reasonable. This represents an over-all rate advance of just about 25 per cent.

Figure 6 shows the approximate total value of fixed capital for 100 water works in New Jersey, together with an indication of the maximum value to which this might be raised if the capital could arbitrarily be increased in relation to the cost index. Actually such a change can scarcely be fully accomplished so that some intermediate point would have to be accepted.

An interesting feature of Fig. 6 is that the long-term trend produces a 1947 capital value 25 per cent greater than the reported figure. It seems reasonable to suggest that an increase in the capital structure—most likely by revaluation procedure—to meet this figure as a minimum would be in order. If other things were equal, a basis for a 25 per cent increase in rates would be afforded immediately. This is not offered as proof of a need for rate increases but as a method of confirming the desirability of a capital increase, as well as to indicate the minimum that should be considered.

Conclusion

The solution is simple to find, difficult to accept and most difficult to achieve. It lies in higher rates for water. To raise revenues from 8 per cent of the true capital value to 10 per cent would require a rate increase of 25 per cent. Few cities can reach this goal without tremendous dissension.

If a compromise must be made, the elimination of discounts and, sometimes, the addition of a surcharge may suffice. In New Jersey, Jersey City raised its rates $33\frac{1}{3}$ per cent in 1947. Trenton has recently increased out-of-city rates nearly as much. The principal obstacle to numerous further increases is the present large dollar surplus occurring in many water departments and companies. Only when it becomes necessary to throw out bids for new work because they exceed estimates (and this happens all too frequently) is it realized that the money available is not sufficient.

Acknowledgments

Appreciation is expressed for the tremendous task undertaken by the A.W.W.A. in compiling the data which have encouraged this study. The present paper by no means exhausts the possibilities of utilizing those results. It is hoped that many water works men can employ the figures to advantage. Further acknowledgment is also given to the many persons who have aided in assembling the figures in the form used in this paper.

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Controlling Industrial Fire Hazards

By Mathew M. Braidech

A paper presented on May 4, 1948, at the Annual Conference, Atlantic City, N.J., by Mathew M. Braidech, Director of Research, National Board of Fire Underwriters, New York.

AMERICA'S present national fire waste demands sober reflection by all the technical, industrial, governmental and educational agencies of the country. The need for greater cooperation and closer liaison between the variously concerned groups is indicated by the steady increase in fire losses during the past five years, and is sharply emphasized by the recent report that the 1947 losses nearly reached three-quarter billion dollars, the highest in all history. This amounts to a daily loss of about $2,000,000, which is roughly equivalent to the occurrence of two major conflagrations per day for a solid year. By another comparison, this staggering sum is nearly 75 per cent greater than the estimated property damage in Great Britain during two years of the German blitz. There is no indication that this tide of destruction has reached its crest; if the losses for the first quarter of 1948 are sustained throughout the year, the final figure may approach or even exceed a billion dollars.

The loss to the national economy is even greater than these figures indicate. They cover direct destruction by fire only and do not include the numerous indirect losses incidental to every fire, such as interruption of business, destruction of vital records and special equipment, loss of market and cancellation of contracts, upset of production schedules and loss of wages and trained workmen, public expenses for fire fighting, and numerous other costly incidentals. Conservative estimates indicate that these losses run from two to three times the direct costs, bringing the total economic loss to well between two and three billion dollars per year. To this total must be added the injuries of some 40,000 persons and the annual death toll of 10,000, which dot this stark scene of fire and explosion. No insurance check can ever reimburse these tragic losses.

An analysis of the tabulated figures of the National Board of Fire Underwriters, over a period of ten years, indicates that one-third of 1 per cent of the fires are responsible for over sixty per cent of the losses, and that these are primarily industrial in character. In particular, records for the past year show that there were close to 200 disastrous outbreaks of fire with losses of $250,000 or over (which include 33 fire catastrophes of $1,000,000 or over each). These large-loss fires occurred in industrial and mercantile establishments, with an increase of 48 per cent in five years. (The severe risk of failure by fire is shown by business mortality figures, which state that every year 43 per cent of the heavily damaged firms do not resume operation and that

another 28 per cent quit business within three years. This offers definite proof that the potential losses, direct and indirect, are substantially in excess of the insurance carried.)

The recitation of the foregoing statistics is intended to alert the reader to the real magnitude of the fire problem and force a consciousness that fire is undoubtedly a far greater destroyer of property than any other element which humans have to contend with. There is no phase of modern life and industry which is untouched by its destructive threat.

Industrial Expansion

It should be mentioned that the value of manufacturing establishments in the United States has been increased by more than 25 billion dollars, coupled with unprecedented congestion, increases in concentration and greater susceptibility to fire damage. The once small, pioneering and individually owned and operated enterprises are today's gigantic industries employing thousands of workers, who comprise a cross section of the variety of attitudes and temperaments of human individuals.

To supply basic needs and ever increasing desires, industry has enlarged production through elaborate machinery and greatly accelerated procceses, involving new and extensive uses of vast quantities of hazardous chemicals, highly flammable solvents and synthetic fuels. Many of these materials and intermediate products have found their way into hundreds of secondary processes and commercial channels, where twenty years ago their use was unknown.

Reference must also be made to the fact that modern research is insuring a never ending change in the industrial and economic makeup. Through this important segment of technical activity, commercial processes have been developed involving the exposure of superlarge equipment to temperatures ranging from ultralow values of 300° below zero to the top extreme of 10,000° F., and to pressure conditions from an almost absolute vacuum to upwards of 50,000 psi. Moreover, the nation is now at the threshold of commercially utilizing the large-scale release of tremendous energies by nuclear fission.

In many of the newer units of industry, progress has been so rapid and so extensive that a considerable number of the processes and their resulting products became accomplished facts long before an opportunity was presented to develop fully the proper safeguarding measures and controls. The phenomenal growth of the plastics industry serves as an index of the typical expansion potential for many new postwar enterprises. The dollar value of this particular industry increased nearly 200 per cent in the past ten years, as compared with about 50 per cent for all other manufacturing enterprises in the same period. The production of plastics has doubled every three years; by comparison, during the rise of the pig-iron industry, its output doubled every eleven years.

In the wake of all this expansion and acceleration, the ever present element of human failure will continue to appear with increased frequency and contribute its proportionate share of incidents through carelessness with matches, open flames and smoking; faulty housekeeping and improper disposal of waste materials; and defective electrical wiring, along with many other so-called "common hazards." With industrial complexity will come certain highly specialized processes and

operations, accompanied by a wider variety of "special hazards." Many with extrahazardous potentialities will demand full-time protection and special fire control equipment.

New Fire Hazards

A brief sampling of noteworthy developments in materials and processes (together with their commercial potentials) may be given to typify the incomparably broad and ramified problems which are currently holding the interest of fire safety specialists:

1. *New chemical developments with hazard potentials.* The nation's capacity for fluorine manufacture was greatly increased during the war to meet the production requirements for the atomic bomb, the demand for special fluorinated chemical compounds for the chemical warfare service, and the petroleum industry's high-octane gasoline program. Industrial electrolytic production of elemental fluorine promises a price drop from the prewar level of $75 a pound to 25¢, with predictions of vast industrial usage. Industrial fluorination is expected to develop a whole series of organic compounds of nonflammable, nontoxic, and high-boiling-point characteristics, finding application in new heat-transfer media, fire-resistive insulation and plastics.

It is to be pointed out that fluorine is an extremely corrosive gas and is recognized as the most reactive element known. Because of its chemical activity, it was found difficult to handle and dangerous to use on any large scale, and defied chemical control for many years. It is capable of producing the highest possible flame temperature (exceeding oxyacetylene flame) and will support the combustion of glass and asbestos; a steel rod goes up in smoke, and water burns as its hydrogen and oxygen combine with fluorine. The handling experience developed during the war should prove most valuable in the proper utilization of this material.

Two important wartime developments have made available low-cost supplies of high-purity oxygen. Tonnage supplies of the so-called "concentrated packaging" of liquid oxygen at −300° F. are now commonly handled in bulk shipment in nonpressured, insulated thermos-type vessels, aboard truck-trailers and standard-size boxcars (containing 62,000 lb. of oxygen, equivalent in capacity to 3,000 standard 2,000-psi.-pressure cylinders, loaded in 11 freight cars). The reduced price of industrial oxygen from $72 to $2.00 a ton is already promoting its use in a new "rich-air" process for making steel, with a promise to reduce cost operations 20–40 per cent. Oxygen-producing units are being installed directly on the premises of large users. One of the newer units is designed to produce 2,000 tons daily, or more oxygen than the entire country produced in 1945, when production was at peak. This low-cost commodity is expected to result in great advances in multiple-torch, heavy-duty flame cutting operations, underground gasification and coal liquefaction processes, the production of high-temperature combustion and highly accelerated chemical oxidation processes.

The other available form of concentrated oxygen appears as 90 per cent hydrogen peroxide in aqueous solution, employed during the war by the enemy to launch buzz bombs. This high-test solution affords 400 volumes of oxygen, in contrast to the 10 volumes of the ordinary 3 per cent pharmaceutical grade. This strong agent may be decomposed rapidly by traces of certain impurities (dusty atmospheres) or by

exposure to heat. The liberated exothermic heat is sufficient to convert the small amount of water to superheated steam with an explosive violence, causing sudden expansion up to 5,000 volumes. Utilization of this product is foreseen in the bleaching of oils, fats and waxes; as a catalyst in many plastics and rubber reactions; and in the manufacture of a whole series of important organic peroxy intermediates.

Certain steels and aircraft metals, such as aluminum and low-magnesium alloys, have stimulated the development of a special heat-treating process involving molten salts over a temperature range of 300° to 2,400°F. Certain of these high-temperature fluids contain sodium and potassium nitrite-nitrate mixtures (for 1,000°F. operation). In the highly heated state, they become powerfully reactive and result in a violent explosion on contact with water or on accidental admixture of extraneous organic or combustible materials (such as the carry-over of oil or cyanide by entrainment from adjoining baths). Overheated salt baths have been reported to undergo a thermit-like reaction with aluminum articles and also cause a destructive attack on the walls of the containers, with eventual structural failure and fatal dumpage into the carbon-fouled combustion chamber.

The use of metallic hydride salts (hydrogen-liberating) for the descaling and "pickling" of metals and alloys is being introduced in industry. These remarkably active and unique metal compounds, along with sodium amide and phosphorus oxychloride, are finding wide use in important organic syntheses.

Rapid-acting chemical agents, such as perchloric acid (involved in the Los Angeles blast of 1947), are increasingly being used for electropolishing, deburring and finishing various metal parts.

Current development work on and use of violently reactive chemical combinations for rocket and jet-propulsion fuels are posing many special safety problems.

Many new high-boiling organic fluids and high-melting inorganic salt mixtures are finding wide uses in petroleum and chemical plants as high-capacity industrial heat-transfer media.

Mass fumigation of warehouses and major structures with thermogenerated insecticidal smokes and ultrafinely dispersed colloidal vapors or "aerosols" is beginning to present new hazards through unsafe solvent carriers and incomplete safeguarding measures.

2. *High-voltage electroprocessing developments.* Extensive developments are occurring in the use of high-voltage electrostatics for spray deposition and dip-detearing of industrial coatings, and in the separation and recovery of fluidized solid catalysts in petroleum-vapor processing.

3. *Fire and explosion hazards in industrial ovens and driers.* To maintain speed of production, drying and finishing ovens are being operated at increasingly elevated temperatures in diversified designs and under complicated operating controls to promote and keep up a high output of work. The occurrence of numerous fires and explosions has stimulated researches concerning the possible catalytic influences of various metal surfaces on lowering the ignition temperatures of flammable vapors and gases; and the redetermination of lower flammability values of these combustibles at actual oven-operating temperatures (ranging upward to 1,000°F.), in contrast to the normally reported data obtained at ordinary room temperatures.

4. *Expanded utilization of liquefied petroleum gases as fuels.* Fuel shortages due to the curtailment of natural and manufactured gases and coal supplies have brought about almost countrywide use of compressed and liquefied propane, propylene, butane, isobutane, and butylene hydrocarbons, with consequent potential leak hazards from these heavier-than-air gases. Protective engineering features and regulations requiring frequent inspection and proper maintenance are being developed to assure a maximum of safety.

Many other new industrial hazards could be added to this list, but it is believed that the foregoing examples give sufficient evidence of the wide range of problems that will continue to tax the ingenuity and resourcefulness of fire protection engineers and the various fire fighting services. It should also be apparent that fire prevention and fire protection are of necessity becoming more complicated, and, to keep pace with the industrial changes, there is a definite need for an increasing amount of scientific knowledge to provide adequate safety controls and greater security against loss of life and property from fire and explosion.

Water for Fire Control

The public water services deserve much praise because of their day-in-and-day-out ability to furnish vital fire protection, and because those in charge have exerted great effort to assure a continuous and dependable supply in all parts of the community. In municipal fire safety rating, the National Board of Fire Underwriters rates water supplies with a top-ranking credit of 34 per cent, the next highest value of 30 per cent being given to the fire department facilities. This 34 per cent rating is greater than the combined credits for zoning, structural conditions, building laws, police protection and fire alarm systems. Water is truly an indispensable factor in fire protection. The best fire department is impotent without an adequate water supply and distribution system.

To comprehend more clearly the role of water in fire control, and to appreciate more fully its potential use in the industrial field, the basic features of "fire control" should be reviewed. Fires and explosions do not just happen, they are nearly always caused by easily controllable and readily preventable conditions. Therefore, most fires may be prevented simply by prior correction of faulty conditions. Fundamentally, it can be argued that the solution to the problems of safeguarding manufacturing operations lies in the modification of the process rather than in the installation of specialized fire protection equipment. Nevertheless, where the degree of hazard is high, a factor of emergency protection should always be provided to meet any dangerous and unforeseen contingency. It does not matter so much how fires start as where they *stop.* Keeping small fires from becoming big fires is the basic premise of fire protection. Regardless of how and where the fire originates, it can be brought under control and extinguished only by removing any one of the three components of "fire": the heat (by cooling below the kindling temperature), the oxygen supply (by smothering to suppress oxidation) or the fuel (by restricting the availability of combustibles).

Water is readily acknowledged as the cheapest and most abundant medium for combating fires, and it will always be the only effective agent for putting out fires of considerable mag-

nitude. However, a review of some of its valuable properties and favorable features may stimulate greater credit for water as an agent for fire control.

Water and water vapor are in themselves noncombustible, thermochemically stable and generally free from dangerous reaction with most materials under usual fire conditions. The *thermal capacity* of water is greater than that of most other common substances; and, on contact with materials at higher temperatures, it will extract more heat from them, weight for weight, than any other substance (the specific heat of incandescent carbon, for example, is about one-half that of water). Water is about the greatest cooling agent—1 lb. will conduct 1,000 Btu. (the complete combustion of wood generates approximately 8,000 Btu.). The amount of heat absorbed by water in changing from a liquid to a vapor is ten times that of any other extinguishing agent. The boiling point of water is low compared with the temperature of various burning bodies; consequently, some of the water played on the fires is evaporated during the quenching. The quantity of heat required to convert water at the temperature of its boiling point to steam at the same temperature is about six times that required to raise it from room temperature to the boiling point. The cooling effect of converting the water into steam is, therefore, about seven times as much as that produced by simply raising its temperature to the boiling point.

Water vapor and steam also act to some extent as a blanket to shut off the atmospheric oxygen and suppress fire by smothering. This is a subsidiary effect and is relatively small compared to the previously cited cooling action. The combined effects of cooling and smothering, however, act together to prevent rekindling and reoccurrence of fire.

Versatility of Water

Water possesses unusual versatility in its application to fire control. It is capable of being applied in many diverse ways for the suppression and extinction of various types of fires * and is easily adapted to automatic control for instant on-the-spot action.

It has been stated by many fire protection engineers that if provided with the required mechanical facilities, in terms of proper equipment and suitable layout, water could put out any fire. Contrary to popular impression, water may be used to control and extinguish certain flammable liquid fires (including heavy industrial marine oils, transformer and lubricating oils, and molten greases, which emulsify readily, while lighter fluids like gasoline, benzol, alcohol and acetone do not). Well-distributed sprays of water impinging on the burning surface of oils produce temporary oil-in-water emulsions with smothering effects.

Since broken water streams do not serve as conductors of electricity, water

* Fires are traditionally classified into three types:

Class A: Fires involving ordinary combustibles (cellulose materials, wood, paper, vegetable fibers, etc.) and solid carbonaceous materials (coal, coke, etc.) in which the quenching and cooling effect of water, or solutions containing a large percentage of water, are of first importance.

Class B: Fires involving flammable liquids, greases, etc., where a blanketing or smothering effect is essential. Usually carbon dioxide gas, vaporizing liquids, foam, sand, and the like are needed to extinguish them.

Class C: Fires involving electrical equipment, where the use of a nonconducting extinguishing agent is essential—generally vaporizing liquids and inert gases.

may be employed to fight fires around electrical equipment at safe distances. Actual tests indicate a definite relationship between voltage, hose nozzle size and distances required. Tests on 1⅛-in. nozzle size for a 5-ma. maximum safe current indicate that with 440 v. the distance required is 2 ft.; with 4,440 v., 20 ft.; and with 22,000 v., 33 ft. These values will vary consistently with the mineral content of the water. The electrical conductivity of deep well water is 1,000–2,000 ohms per milliliter; the figure for lake and river water is 4,000–5,000 ohms. Sea water and discharge from a soda-acid extinguisher may have such a high conductivity that no rule can be applied as to safe distances.

The recognition of certain other favorable properties of water will tend to promote its judicious use in general fire safety methods. The solubilizing properties of water will find great application in diluting flammable solvents and dissolving combustion-supporting chemical compounds, to retard combustion and the evolution of combustible vapors. This causes the extinction of fire through a fuel removal process. Because of the large quantity of water required, however, the method may not always be practicable.

Most of the toxic residual gases of fire (hydrocyanic acid, the oxides of nitrogen, hydrochloric acid, sulfur dioxide, ammonia and various organic vapors, such as acrolein and the aldehydes) are appreciably soluble in water (carbon monoxide has a low solubility of 30 ppm.) and can be reduced to low concentrations. Hindering smoke and fumes, usually encountered with slow-burning and smoldering fires in basements and below-grade areas, may be effectively cleared away with water streams.

Applied in an intelligent and judicious manner (to avoid violent steam generation, spattering and spread of fire) overheated chemical masses and salt baths may be cooled to safe levels with water. Certain active chemical compounds undergo favorable endothermic (heat-absorbing) change on contact and solution with water; deluging with a copious quantity of water is dictated, for example, in ammonium nitrate fires (a most serious oversight at Texas City), *in contrast to the opposite requirement* for overheated salt bath materials, sodium and potassium nitrates.

Emergency streams of water may be applied to compressed or liquefied gas systems to confine spillage and seal off accidental leaks, through the freezing of the applied water due to the temperature drop effected by the escaping gas (adiabatic expansion).

Contrary to the usual fire fighting procedures—in which the first step is to extinguish the fire directly—when certain highly volatile hydrocarbons (such as butadiene) are involved, the fires should not be extinguished until the fuel is exhausted; otherwise the outpouring of large quantities of unburnt vapors can produce a menace to the surrounding territory and personnel. To provide protection, sprays and water curtains are utilized to encompass such hazardous areas and restrain the lateral spread of vapors and the transmission of fire—by radiation and convection—to near-by storage tanks and adjacent properties. Fixed sprays are also built around various columns and supporting beams of open steel structures (the typical construction in hazardous chemical processing, synthetic rubber and petroleum refining, for example) to cool and prevent their collapse, and minimize fire damage to

reaction vessels, fractionating towers and other processing equipment within the structures.

The adaptability of water to automatic, high-speed application is evidenced by the outstanding record in the control of flash fires during the manufacture of rocket powders, where suitable detection devices and closely located nozzles permitted action in 0.2 seconds and total extinguishment within a few seconds. During the war, some 46,000 fire outbreaks were thus successfully controlled with small damage and no personal injury beyond minor burns.

To prevent the accumulation of electrostatic charges and spark-over in hazardous locations, slight conductive films of moisture and atmospheric grounding can be supplied through humidification with water atomizers and vaporizers.

Another illustration of the versatility of water as an extinguishing agent is its application in the solid or frozen form. Recent army experiments demonstrated the feasibility of successfully extinguishing fires under subzero arctic conditions with snow or finely crushed and flaked ice, produced by portable mechanical ice-crushers and expelled by a flexible hose. This scheme has been found most effective in combating gasoline-spill fires and tub fires involving naphtha and diesel fuel oil.

Recent Developments

Two relatively recent developments—mechanically conditioned "water fog" and chemically conditioned "wet water"—appear to hold much promise for widening and enhancing the range of effectiveness of water in almost all classes of fires.

The discharge of water in a finer state of subdivision from high-pressure nozzles and specially designed heads (100–600 psi.) has demonstrated appreciable improvement in fire extinction. The greatly extended surface area is said to promote speed of heat transfer and quicker cooling effects, in fires of moderate size. It may be possible to suppress "flash combustion" and the explosion of flammable vapor-air mixtures by retarding flame propagation through a dampening effect of the suspended aqueous mists. The rate of absorption of toxic fire gases and "knockdown" of smoke is also greatly speeded up by the application of fog. Atomized water streams very much reduce the danger of carrying current when employed around electrical equipment. Safe distances are reduced to 5–10 per cent of those for ordinary hose streams. Reported data give 24 in. for 33,000 v.; 32 in. for 50,000 v.; 64 in. for 110,000 v.; and 124 in. for 220,000 v.

Water fog is being successfully used to control fires in oil-quench tanks and varnish and lacquer kettles, to protect costly refinery and chemical plant equipment. Hose lines are being equipped with combination nozzles, permitting material variation in the type of streams—fog, spray, or solid full-nozzle flow—as may be required. Firemen can thus provide for themselves, at will, a protective fog or spray screen for closer approach and a projection range of a solid and heavier stream to reach the burning material itself and drench the actual seat of fire. Recent installations of subtransformers and switch points on high-tension networks are being equipped with thermostatically controlled water fog systems

to give automatic protection, particularly in outlying areas.

Developments in the so-called "wetting agents" for the purpose of increasing the fire extinguishing power of water are now holding the interest of the fire fighting field. Investigations under way are to determine the corrosive, toxic and electroconductive properties of such conditioned water, and the extent to which this treatment may be applied to wet down water-repellent dusts, smokes and fumes for fire prevention. The possibility of promoting emulsification and foaming of alcohols and other nonfrothing liquids for fire protection is also being studied. One of the principal requirements for an extended use of wetting agents is the development of a suitable proportionating feed device to meet the variable service conditions in the field.

Reference should be made to the standard automatic sprinklers and their most excellent record in controlling fires over a span of years. There are about 250,000,000 sprinkler heads now in service, standing as sentinels over $50,000,000,000 worth of property in this country. Fire loss on such property has not been more than 10 per cent of what it would have been without this protection. Lacking such equipment industry never could have developed along the present lines of large areas, hazardous occupancies and concentration of high values.

In the face of this rising technological tide, it is impossible to adopt the King Canute attitude of demanding that industry stand still. Preventive measures and protective safeguards must be constantly improved to keep pace with ever changing conditions.

Flow Requirements for Fire Protection

By A. C. Hutson

A paper presented on May 4, 1948, at the Annual Conference, Atlantic City, N.J., by A. C. Hutson, Asst. Chief Engr., National Board of Fire Underwriters, New York.

IT has been generally accepted that the fire flow need in any city or town depends upon the size and value of the most congested high-value area, which usually is the principal mercantile district. It has also been recognized that these areas do not greatly vary for places of the same population and that with population growth there is an increase in values and in the extent of the district.

In 1911 Metcalf, Kuichling and Hawley (1) prepared a formula for fire flow, based upon surveys by the engineers of the National Board of Fire Underwriters. This formula was $G = 1{,}020\sqrt{P}\,(1 - 0.01\sqrt{P})$, in which G was in gallons per minute, and P was the population in thousands.

It will be noted that this formula gives a zero requirement at 10,000,000 population and negative figures above this population. This does not mean that cities of such size need no fire flow, but it does fit in with the concept that for very large cities the consumption demands are so great it is not necessary to add much capacity for fire demand.

The engineers of the National Board of Fire Underwriters found that there frequently had to be material modifications. For example, the communities suburban to a metropolis seldom had a business district which required more than 5,000 gpm.—corresponding to a population of 28,000—although the actual population might be up to 75,000. On the other hand, there were cities of small area which might have an extensive mercantile district because of a large trading region surrounding the city.

For an individual fire involving a single building or even a major portion of the buildings in a city block, it is doubtful if sufficient hydrants, hose and men can be made available to handle more than 12,000 gpm., which corresponds to a population of 200,000. However, for cities over this population, there may be a second fire for which 2,000 to 8,000 gpm. may be desired.

It will be noted that 20,000 gpm. would be the maximum fire flow demand required for any city. With fire departments equipped with automobile apparatus, there have been concentrations of fire companies from outlying areas and from outside communities, at times of conflagrations, which have resulted in an actual use of water in excess of the specified fire flow requirement. To provide, in part, for such a condition, it is the practice to ask for the required fire flow to be available when consumption is at a rate corresponding to the maximum day's demand within the past three years.

The fire flow demand for portions of a city other than the principal high-

value area is usually based upon the degree of congestion, the size of the buildings, their occupancy and the size of the fire department. There are many places where individual buildings or groups of buildings require a larger fire flow than that called for in the principal mercantile district. In the past, determining the fire flow required for these other sections has been largely a matter of judgment. To establish some degree of uniformity, a method of determining the fire flow requirement is given in this paper.

Residential Requirements

In considering the fire supply for individual buildings, the first factor is the supply available from the individual hydrant. The size, length and method of supplying the mains should be such that each hydrant to be considered as providing protection would deliver two good fire streams. This means a minimum of 500 gpm. from each hydrant.

For a building of small area and low to moderate height, such as an eight-room two-story dwelling, the availability of one hydrant should be sufficient, if at least a 30-ft. separation of buildings is provided on all sides. Where this separation does not exist, there is the probability of two or more buildings becoming involved; with a mild degree of exposure—that is, one side—two hydrants, each within 500 ft. and each capable of delivering 500 gpm. of water, will be needed. A moderate exposure—on each of two sides—will require a total available fire flow of 1,500 gpm., and when the blocks are built upon with all lots occupied on the street front, the danger of a fire involving several buildings may well require 2,500 gpm.

Where dwellings are 2½ or 3 stories high, of more than eight rooms or with living quarters for two to four families, the quantities required would be 50 to 100 per cent greater than these figures—that is, no exposure, 1,000 gpm.; mild exposure, 1,500; moderate exposure, 2,500; and severe exposure, 5,000 gpm.

Individual unexposed buildings of the order of hotels, dormitories, apartment houses and high-value residences will require from 1,500 gpm. for those of one or two stories to 3,000 gpm. for those over four stories. Densely built sections of three-story and higher buildings of residence occupancy may need up to 6,000 gpm.

Industrial Requirements

The question of water for fire protection for industrial plants was discussed in 1924 by Siems and Biser (2). Because of the present tendency of industry to locate in the outskirts of cities, or beyond the city line, it appears well to assess again the various factors involved.

1. The area of a building is a major factor, as fires can be extinguished with water only by applying it on the burning material. With normal ceiling height, the reach of a stream inside a building may be considered as 50 ft., and never over 75 ft. The vantage points from which streams can be delivered are limited to doors and windows, and many parts of a building, even if the stream is not obstructed by partitions or piled goods, will not be reachable from the exterior through the usual openings.

Considering area alone, a building 50 × 50 ft. might well require the use of two good 1¼-in. fire streams from one side, or a total of 600 gpm. Since the water actually used is about two-thirds of the required fire flow, a 1,000-gpm. fire flow is needed for the ordi-

nary building which is 2,500 sq.ft. in area.

As the area covered by a building increases, it appears reasonable to add to the fire flow requirements, up to a fire flow of 5,000 gpm. (or the use of ten good 1¼-in. streams), beyond which the factor of area is no longer the one to be considered.

2. The height of a building adds to the fire flow requirements largely because the use of turret nozzles, ladder pipes and water towers, each with streams of 600 to 900 gpm., is necessary to control the fire in the upper stories. For one 600- to 900-gpm. fire stream, it is fair to assume a fire flow of 1,000 gpm. The need of such streams increases as the height exceeds two stories.

3. Where buildings are not isolated, nor in outlying sections of the city, nor with an 80-ft. or better separation from other buildings, the danger of a conflagration heat wave, which requires large quantities of water, must be considered, both from the standpoint of a fire in the plant spreading to other property and of a fire in other property exposing the plant to danger.

In general provisions for this contingency must be a matter of judgment, taking into consideration whether the plant is in the center of an extensive built-up area or in the outskirts, and also the type and value of the district from a conflagration point of view.

4. Because of greater safety to firemen in fighting in the interior, buildings of fireproof or semi-fireproof construction will not require as much water as those of other types. This factor again must be left to individual judgment.

5. The nature of the contents might have a marked influence on the amount of water needed. The character and amount of material in storage and in process varies from year to year, but fire protection must be fixed for the most severe condition expected from whatever occupancy there is.

6. Private protection will often reduce the fire flow required from the municipal water system. Automatic sprinklers make it much less probable

TABLE 1

Industrial Fire Flow Requirements

Item	Formula	Maximum *gpm.*
1. Ground area of building, in square feet (A)	$1{,}000 + \frac{A}{10}$	5,000
2. Height in stories (H)	$500(H - 1)$	3,000
3. Exposure	Judgment	2,000
4. Credit for fireproof construction	Not to exceed ⅓ sum of Items 1–3	
5. Credit for nonhazardous materials	Not to exceed ¼ sum of Items 1–3	
6. Credit for automatic sprinklers and other protective equipment	Judgment	3,000
7. Size of fire department*	500 gpm. per 50,000 pop.	2,000
8. Minimum based on response to first alarm	500 gpm. times no. of fire engines	

* A function of population; 500 gpm. is required for each 50,000 pop. *in excess of* 100,000.

that a building will be involved in a large fire, but such systems are not designed to furnish full protection for all occupancy or for a severe exposure, nor should the possibility be overlooked of the system being out of commission or being shut off too soon, or of the pressures being lowered through the use of water by the fire department.

Judgment must be exercised to determine the permissible reduction for sprinklers, standpipes, automatic fire detecting systems and special protective equipment for hazardous processes.

7. Any serious fire may call out the major part of all of the fire companies, and in some territories there may be an extensive response of outside aid. Fire fighting is emergency work not capable of being standardized, with the result that it is a general policy to use all fire companies thought needed. Under these conditions it is not uncommon for the distribution system to be overtaxed, with a possibility that the most needed fire streams will be ineffective in volume and reach.

The quantity of water and the number of fire stations needed for the protection of a city are, in general, a function of the population. This, in addition to the question of the protection of the principal mercantile district, might well be a factor in the determination of the fire flow required in industrial areas.

8. Minimum fire flow requirements are based on the apparatus responding. A first alarm response of fire apparatus ranges from two pumpers, of 750 to 1,000 gpm. each, for places of under 50,000 population, to 4 pumpers in places of over 100,000. In general the minimum required fire flow, even though all buildings are fireproof and protected by sprinklers, should be a proportion of the combined capacity of these pumpers.

The fire flow requirements based on the eight items just discussed are summarized in Table 1.

For industrial buildings the question of normal and residual pressures is a vitally important one. It is recognized that most fires are small when discovered and can be readily extinguished. In fact, 60 to 70 per cent of all fires are extinguished before the damage exceeds \$100. These fires account for only 5 per cent of the total fire loss of the country. Water is the most effective agent for extinguishing nearly every type of fire, if properly applied.

To provide for fire fighting by the occupants before the arrival of the fire department, pressure on the top floor of the building must be 20 to 25 psi. Few modern industrial buildings exceed four stories, for which another 20 psi. should be added, and thus a total minimum pressure of 40 psi. should be available at ground level; 60 to 75 psi. will allow for losses in pressure during high consumption, and pressures up to 100 psi. have proved not to be objectionable.

The fire flow for ordinary fire department use is generally figured for a residual pressure of 10 psi. where only large hydrant outlets are used, and 20 where small outlets are available; this is enough to overcome friction losses in the hydrant branch, the hydrant and the suction hose, and leave a positive pressure on the suction side of the pumper.

The general practice is to consider a municipal system satisfactory for sprinklers if it produces, at a residual pressure of not less than 15 psi. under the roof, a flow of 250 gpm. for light-

hazard occupancy and 500 gpm. for ordinary hazard. For extrahazardous occupancy, special consideration is given to quantity and pressure.

The chief problem today is that of industries which are outside the city limits, or inside but on the outer fringe of the distribution system. Even though the buildings may be of superior construction and the contents may not be extrahazardous, these plants are usually large enough to justify classifying them as needing more water than the 500 gpm. indicated above. It is obvious that, upon the arrival of the fire department and the use of hose lines, the supply to the sprinkler system will be inadequate. Connecting up one of the hose lines to supply the sprinkler systems will not remove the inadequacy, because a single line will seldom provide as much as 500 gpm.

In addition to this possible failure of normal supply, past records show that many serious fires in sprinklered buildings have occurred because of a closed valve or some other derangement.

Considering all phases of the question, there can be no doubt that it is reasonable to reduce the required fire flow for a sprinklered building to a figure substantially lower than that of a similar building and occupancy without sprinklers. However, this required fire flow must at least equal that specified for supply to the sprinkler system, plus a reasonable amount for the use of the fire department as hose streams. Furthermore, this required fire flow should be available at a residual pressure sufficient to give 15 psi. on the under side of the roof.

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The Water Works and Fire Protection

By Samuel F. Newkirk Jr.

A paper presented on May 4, 1948, at the Annual Conference, Atlantic City, N.J., by Samuel F. Newkirk Jr., Engr. and Supt., Board of Water Commissioners, Elizabeth, N.J.

IN the author's opinion, reasonable requirements governing the quantity of water for fire prevention and extinguishment, and the length of time this amount should be available, are outlined in the Standard Grading Schedule of the National Board of Fire Underwriters. The quantity required is based on population probably because no better unit is obtainable. Population, however, does not always serve so well as a base, as it is very obvious that the fire flow requirements for a residential community in a metropolitan area should be less than for a district with the same population located at some distance from other communities. This situation is usually, if not always, carefully appraised by the underwriters when applying the grading schedule.

Private Charges

The author, however, is not in agreement with those who recommend that there should be no charge by the water utility for private fire protection on the premise that any private protection is an extension of public fire protection, that it is a substitute for the demands of public fire service or that fire protection is something to be paid for by the municipality as a whole.

It is thought that taxpayers as a whole should not carry the,cost of special service to a relatively few individuals who wish to take advantage of fire service capacity in a particular way—not *instead* of the public service but *in addition* to it—and who want protection against a special hazard which they create or which is inherent in their business.

Some insurance interests agree that those desiring private fire protection service should pay all construction costs and a nominal yearly maintenance fee.

Fire Line Meters

A water operator also will disagree with any agency opposed to meters on private fire service connections. Very often fire line meters have indicated that water was being taken from fire lines other than for fire fighting, a situation which would not have been detected without the meter. This misuse of fire lines sometimes is temporary and often without the knowledge of the owner of the premises. An unmetered fire line is so accessible for connection that it is no wonder an operator is concerned, since illegal connections from buildings have been made even by tunneling under street pavements. Twice in the past year alone the misuse of private fire services has come to the attention of the Water Board in Elizabeth, N.J., which is a small community with relatively few—43—fire service connections. In one

plant, a plumber connected a washroom tap to the nearest water pipe, which happened to be a part of the automatic sprinkler system; in the other, a manufacturer took water from the fire system while private wells were being reconditioned. These violations would not have been discovered if there had been no meters on the services.

A neighboring municipality with a policy of not installing meters on fire services recently discovered that water was being used illegally through such a service. The offender settled for $9,700, and the municipality immediately changed its mind about fire line meters.

Fire Service Connections

A water superintendent is often in disagreement with designers and contractors concerning the size of a fire service connection. It is generally thought by water operators that the connection at the street pipe should be one size less than the street pipe, with a maximum of 8 in. For example, a 6-in. street pipe should not have a connection larger than 4 in., but the connection could, however, quickly be increased to 6 in.

Sometimes, although objections have been made to a 4-in. connection increasing to 6 in., permission has been given by the insurance interests for a 2-in. connection to be made before the meter for purposes other than fire fighting. Insurance agencies have also permitted connections for purposes other than fire extinguishment on the customer's side of the meter, without consulting the water utility.

Separate Fire Fighting Systems

At the President's Conference on Fire Prevention, held in Washington in 1947, seventeen specific recommendations were made for action in the field of fire prevention. The only one that concerns a water works official as such states: "The traditional design of public water systems for fire protection should be reviewed in the light of war experience."

As far as the author has been able to ascertain, this recommendation is based on the idea of providing local storage of water for use in combating fires started by aerial bombing—the storage not to be affected by breaks in the street pipes. It has been suggested that cities build separate fire fighting water systems consisting of a large number of individual units, each to protect a city block or group of blocks. Every unit is to have a gravity tank for its primary supply, ground tanks or reservoirs for secondary supply and the connection to the supply from the street pipe normally is to be closed, so that water will not escape if any pipe outside the unit should fail.

It should be remembered that European water systems are designed primarily to supply water for domestic use, and little attention is given to the supply for fire fighting. In the United States, on the other hand, the provision of an adequate supply for fire fighting has for many years been considered as important as supplying domestic water. It must also be remembered that water distribution systems in the United States are better equipped with gate valves for controlling water at pipe failures than are those in Europe.

It would appear that the installation of separate water systems for fire fighting is impracticable and unsound economically. If there are funds available for the construction of separate systems, they might better be expended on

additions and improvements to the existing water system.

Large Fire Pumpers

Attention was recently called to the trend toward providing larger-capacity automobile pumpers for fire department use, and it was indicated that units of 2,000-gpm. capacity are now being manufactured. In one city two units are in service with a capacity of 3,000 gpm. each. If a supply for such large-size pumpers is to be obtained from the domestic water system, it means a complete overhauling of the fire hydrants and street pipes in practically every city in the country, and the tremendous expense does not appear to be warranted.

The average fire stream ranges from 250 to 300 gpm. In the larger cities the 750-gpm. pumper for each fire company appears to be all that is necessary, for, even in the best manned fire departments, there are not enough men for a company to handle more than two powerful exterior streams or three streams on the interior of a building. Those companies located in the high-value districts of the larger cities may require an individual pumper capacity of 1,000–1,250 gpm., but this should be sufficient to supply as powerful a stream of water as appears to be necessary in fire fighting.

The installation of larger-capacity pumpers does not increase the reliability of service, nor does it make it much more adequate. It is questionable whether there would be sufficient manpower to lay the hose and otherwise place the full capacity of the larger units in service. The inability to use large quantities of water from a single source has been demonstrated by the failure to use effectively even a portion of the capacity of a fireboat on land fires.

Wetting Agents

Articles recently published in popular periodicals and the technical press have shown a growing interest concerning the use of wetting or surface-active agents in the extinguishment and control of fires. It does not seem too much to hope for that some synthetic detergent may be found which will reduce the quantity of water required for fire department use.

The wetting agents commonly used are sulfates and sulfonates of alcohols, coal-tar, or petroleum derivatives. When added to water they improve its wetting efficiency by opposing the forces that tend to make a globule of water hold its spherical shape. This makes it easier for water to extend itself to cover small particles of other substances or to penetrate into cracks and crevices. Water treated with a wetting agent does a better job of extinguishing certain types of Class A and Class B fires than plain water similarly applied.*

In an effort to obtain further data on the comparative value of wet water and plain water in different types of fires, a number of experiments have been made. In a test on a burning crib of fir two-by-fours, water spray containing a 2 per cent wetting agent solution extinguished the fire three times faster than plain water. In another test, a 2 per cent wetting agent solution from a spray nozzle at 20-psi. pressure extinguished a kerosene fire in half the time required for plain water spray at double the pressure.

The most promising fields of application at the moment appear in fires of combustible materials which are difficult to saturate with ordinary water

and in fires where water supplies are limited. Examples include forest fires in dry, dusty humus; fires in coal piles; and fires in fibrous materials like cotton. The extinguishing capacity of an ordinary pump tank can be roughly doubled by utilizing a wetting agent.

Several features, however, still need investigation, including the electrical conductivities of wetting agent solutions in spray and solid streams, the proper methods of application and the effect of wetting agents used in chemical extinguishers.

As the technique of applying wet water improves, the employment of this modern extinguishing agent will increase. Already used in small, straight streams, treated water may eventually find application in heavier streams and larger hose. The use of wetting agents by a standard fire department pumper, either through its booster tank and hose or by by-passing the booster tank with a proportioner, seems practicable and would require no special changes or adjustments in the apparatus, hose or fog nozzles.

Public Use of Reservoir Lands and Waters

By Richard E. Bonyun, Gerald E. Arnold, Eugene F. Dugger, S. T. Anderson, Edward S. Hopkins, Charles E. Moore and Harry B. Shaw

A panel discussion presented on May 6, 1948, at the Annual Conference, Atlantic City, N.J., with L. S. Finch, Chairman, Subcommittee on Public Use of Watershed Areas, as Moderator.

Richard E. Bonyun

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That good public relations is a very important factor in conducting any business or enterprise today is well known. This applies to the operation of public utilities as well as to manufacturing and sales organizations. The fact that the public utilities, such as telephone, electric, gas and water, generally constitute a monopoly and are not usually subject to competition in their respective areas makes it all the more essential that good public relations should not be overlooked. Perhaps the water works industry has been most remiss in this field, compared to other industries and utilities. Water utilities have kept up with the times in regard to advances in water works construction, treatment methods, pumping and distribution, but the public today has learned to expect consideration and good service. Gone are the days when the water purveyor could adopt a "take it or leave it" policy or establish restrictions without good and substantial reasons for them.

The public use of reservoir lands and waters could play a significant part in the public relations program of almost every water works system. Today, when nearly every family has an automobile, the trend is for people to travel to the country for their recreation and relaxation. The public is looking for open waters for bathing, fishing and boating, and for wooded and open areas for picknicking, hiking and playgrounds. When people see the beautiful reservoirs, lawns and woodlands which are owned by the water supply systems, it is no wonder that they ask permission to use them for recreation.

To deny permission certainly makes for poor public relations. On the other hand, the water purveyor's first responsibilities are to furnish a pure water supply for the consumer and to protect the property investment of the water works system. It appears that a happy medium can be arrived at by the establishment of a policy or rules and regulations to fit the particular water utility. In dealing with this subject, certain considerations must be kept in mind:

1. *Nature and source of supply.* The source may be a water supply reservoir, a large lake or a river with little or no storage.

2. *Extent of water treatment.* In guarding against possible pollution due to the public use of reservoir lands and

waters, the extent of the purification treatment of such waters must, of course, be considered.

3. *Time element—period of storage.* Water naturally improves with storage in many respects. According to various authorities, over 95 per cent of the typhoid bacilli discharged into surface waters die during the first week and after one month the bacilli have practically ceased to exist. The surviving minority may persist for two months or longer. Therefore, in a large water supply reservoir, for instance, if the water is stored for 90 days before it reaches the outlet, the danger from pollution is greatly minimized.

Of course, certain parts of the water works land should be excluded from public use, such as the areas around the intake and headworks. Distribution system reservoirs storing filtered or purified water should be barred to the public.

Bathing Restrictions

Bathing in a potable water supply reservoir should be prohibited, even though the danger from pollution might be remote on account of the length of storage or the purification process utilized in the system. Bathing in such water should be prohibited even for no other reason than that the thought of bathing in the drinking water supply is repulsive. If the source of supply is from a large river or lake where little or none of the drainage area is owned by the water purveyor, it is, of course, difficult to control public use of the waters or the land. Attempts have been made, however, to restrict or control bathing in such places. A bill has been introduced in the New Jersey legislature which would prohibit mass commercial bathing in waters tributary to a potable water supply shed, except under permit from the State Department of Health. As might be expected, considerable opposition to such legislation exists.

Reasonable Use Permissible

There is a large public demand for fishing and boating on water supply reservoirs. It is the author's opinion that if the supply has the protection of a sufficient storage period and if it receives purification treatment—at least sterilization by chlorination—a certain amount of fishing and boating can safely be allowed. Perhaps one of the best ways to permit such public use is to prohibit fishing from the shoreline and allow it only from a boat or boats furnished by the purveyor after a day permit has been obtained.

The public use of reservoir lands also may be permitted, provided that certain areas are designated for that purpose and proper sanitation facilities have been supplied by the water works operator. These areas should not be close to the intake nor should they be on the headworks grounds. It does not seem fitting that the headworks grounds and lawns be turned into public parks, and for that reason it is seldom, if ever, done. Designated areas in the remote portions of the watershed should be equipped with fire places, benches, tables and toilet and other sanitary facilities, and should be under the supervision of the reservoir police or guard force. It would be unwise to have these areas close to the reservoir shoreline, since the temptation to bathe or wade in the water would be great and difficult to control.

It has long been a problem in a large water system with reservoirs and extensive land holdings to keep the public

out of restricted areas, the use of which might constitute a hazard to the public water supply. It is far better to designate, equip and supervise the use of certain areas, or to permit fishing on a limited and organized basis, than to be constantly fighting with the public to enforce a no-fishing and no-picknicking policy, which everyone knows cannot be completely enforced. If public use of reservoir lands and waters constitutes a hazard to the public water supply, it seems practical to direct such use and minimize the hazard rather than to have the hazard exist but be unaware of its extent. Such a policy, if adopted, would do much to further good public relations.

Gerald E. Arnold

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The author believes that the public relations of water utilities can be decidedly improved if moderate use of watershed lands and reservoirs, under proper control, is permitted for recreational purposes. This operation should be confined to those localities where there are no other suitable facilities for such activities. In large areas of the country there are many lakes available to the public, but in other places, particularly in the southwest, all the fresh water lakes are water supply reservoirs. It is the author's opinion that where such conditions exist, the use of the lakes for public recreation is justified. Suitable sanitary facilities must be provided, however, and adequate control exercised.

It has long been the policy of the city of San Diego to permit hunting, fishing and boating on water department reservoirs under strict supervision. It should be pointed out that the water supply for San Diego is normally filtered after withdrawal from these reservoirs and that strict sanitary control is exercised at all times. The department owns and operates the boats and facilities, and its employees are in responsible charge of activities at the reservoirs. Permits sold to the public at the lake are required for hunting, fishing and boating. Adequate sanitary facilities are provided around all of the lakes and their use is enforced. Suitable fish-cleaning tables located adjacent to the reservoirs are screened and equipped with running water and waste receptacles. Picnicking is permitted at several of the reservoirs; camping at only two. In camping areas water flush toilets and septic tanks are provided, and careful attention is paid to their proper operation.

Because of inadequate filtration capacity, two of San Diego's reservoirs have not been opened to recreational activities. Comparative studies of the pollution of open and closed reservoirs have disclosed no indication of increased pollution in those reservoirs that are open. Reservoirs now closed will be opened as soon as additional filtration capacity, now under construction, is completed.

The author fails to see how the water works industry is justified in prohibiting recreational activities on water supply reservoirs so long as such activities are properly controlled and the water is adequately treated. The slight potential pollution load brought about by recreational use can hardly be compared to the known heavy pollution load caused by sewage discharged to rivers in some sections of the country. The author feels that the safe quality of the water should be assured by treatment rather than by protection of the supply. The public in general is made

happier, and public relations are much improved, by permitting modified recreational activities on water supply reservoirs when there are no other such facilities available.

Eugene F. Dugger

Gen. Mgr., Newport News Water Works Com., Newport News, Va.

Reliance on governmental assistance has become so widespread that more and more privileges are being sought by organized minority groups from national to municipal levels. So-called sportsmen's groups have practically demanded that impounding reservoirs of the local water supply be opened for fishing and other water sports. Little thought is given by these groups to the reasonableness of their requests. Certain reservoirs in tidewater regions are located in drainage areas where sanitary facilities are impossible to install without having the drainage return to the lake. Where such conditions exist these requests cannot be granted without materially increasing the bacterial count of the raw water.

The ideal impounded supply comes from an area free of human habitation. For this reason, the Newport News Water Works Commission owns or controls the entire drainage area supplying the lakes which provide the water for the Lower Virginia Peninsula. Some of these parcels of land have seemed extraordinarily expensive but the management has felt that their purchase was justifiable. To accede to the demands of local groups to open a lake where sanitary facilities cannot be installed would defeat the entire purpose and policy of such long standing.

General experience shows that even where it is possible to furnish sanitary conveniences so that drainage will not return to the impounded supply, there are always a few perverse individuals who will not use the facilities provided and will not hesitate to pollute the water supply.

The enforcement of regulations regarding fishing in water supply reservoirs can be an extremely troublesome and time-consuming operation which has a tendency to detract from the efficiency of regular water collection and supply operations. The provision of sufficient watchmen to insure compliance with sanitary regulations is expensive, particularly today, and the cost can easily exceed the income from any reasonable fees that might be charged for fishing privileges.

Adverse Effects of Privileges

From a public relations standpoint, the benefit of permitting such use is very questionable. To set up and enforce sanitary regulations and limit fishing to hours when it can be supervised by watchmen makes for discontent on the part of the very people who have been granted the privilege and tends to nullify any gain made in public relations.

If a system has a number of reservoirs situated in varied physical surroundings, the precedent established by allowing fishing in one reservoir makes it difficult to refuse similar privileges in others. By the same token, the practice of one water department in allowing boating and fishing in its reservoirs makes it hard for other water systems in the vicinity to explain satisfactorily why they cannot grant similar privileges. People who wish to fish will not see the distinctions which may exist among water supply reservoirs because of their function and environment.

The more examples that can be pointed to of such privileges being granted, the worse the public relations become in a community where they cannot be allowed.

Furthermore, the granting of any type of special privilege seems inevitably to lead to requests for additional privileges, and to discontent if the latter are not granted. Where boating and fishing are allowed, the privilege of swimming in lakes will be the next to be asked, and, as a rule, people who desire special privileges not granted to the general public cannot be appealed to by argument and reasoning. They would quite likely refuse to see the distinction between boating and swimming. As a matter of fact, with regard to opportunity to pollute the reservoirs, it is difficult to demonstrate that there is a great difference between the two.

Again, when privileges are granted to only a few people—and usually only a small proportion of the consumers in a community desires to fish—the public generally is apt to be critical of things which otherwise might pass unnoticed. For instance, should there be an outbreak of digestive illness in a community which allows fishing in its water supply ponds, the majority of the population would be much more ready to blame the water and much less easy to convince that the cause lies elsewhere.

One of the lakes at Newport News is so constructed that sanitary conditions can be properly maintained below the dam and there are adequate parking and picnic areas adjacent to it. The lake has been open for fishing and boating for a number of years, with the exception of the war period. These privileges are used by comparatively few local citizens and their value for public relations is very doubtful.

The majority of the citizens agree with the policy of the management that the pollution of the raw water supply should be held to a minimum and that, as a consequence, the lakes should not be opened to the general public for any purpose.

S. T. Anderson

Gen. Supt., City Water, Light & Power Dept., Springfield, Ill.

When the proposal for a bond issue to finance the construction of Lake Springfield was presented to the Springfield, Ill., voters, they were promised that the recreational facilities of the lake would be developed.

In planning the lake it was decided to purchase several thousand acres of additional land. This was done for two reasons: first, to give the city control of the entire shoreline, from a depth of a few hundred feet to a distance of one-quarter to one-half mile, in order to cope with erosion and protect the supply from pollution; second, to allow the shoreline to be developed for home sites and public recreation.

All of the land bordering on the main body of the lake was subdivided into areas for homes and parks. Roads and driveways were constructed, and water mains, sewers and electric lines were installed. Five parks were developed by the construction of fire places, picnic tables, comfort stations, ball parks, horseshoe courts and other types of playground facilities. Two beaches were built, together with beachhouses. These beaches were covered with thousands of tons of sand and were equipped with diving towers, slides and safety equipment. They were operated at as near cost as possible to concentrate all

swimming at these controlled points. Boat dock concessions and the privilege of conducting excursions were leased to a private company. A number of areas were let to private groups who operated facilities for sail and motor boats. All boats were licensed after inspection by the department and were operated under an ordinance providing safety regulations.

As the lake filled, it was stocked with several kinds of game fish. Since that time the department has constructed two rearing ponds to raise black bass and restock the lake.

Water Department Supervision

All of the marginal land remains under the supervision of the water department. Its operation is classified into several subdivisions:

Real estate. The Superintendent of Real Estate handles all leases and associated problems. The lots are leased to groups as clubs or to individuals as custodians for periods of sixty years.

Construction. All construction of any nature, including buildings, garages, boathouses and separate sewage disposal systems, must be approved and inspected by representatives of the department. All electric lines, water distribution mains and sewer mains are installed by the department.

Source of supply. The lake proper is under the supervision of the Superintendent of the Source of Supply, whose jurisdiction includes roads, dams, bridges, sewers and riprap.

Recreation. Recreational facilities, including the operation of beaches, parks and playgrounds, as well as picnic areas, are the responsibility of the Superintendent of the Source of Supply.

Nursery. During the construction of the lake a nursery department was set up for reforesting and planting ornamental shrubs on all of the marginal land. A landscape architect was employed to lay out the planting along the roadways and through the park areas. Over 5,000,000 trees have been used in the reforesting. Thousands of flowering shrubs for decorative purposes were planted under the supervision of the landscape architect. The farming areas which have not been developed for real estate or park purposes are operated under the nursery department.

One of the outstanding developments of the lake is the Abraham Lincoln Memorial Gardens, located on a marginal land area which was turned over to the Garden Clubs of Illinois. In a picturesque setting on the rugged shoreline fronting a wide expanse of water, the garden clubs have constructed a living monument to the memory of Abraham Lincoln by planting native trees, flowering shrubs and wild flowers over the entire area.

Another portion of the land has been set aside as a wildlife sanctuary. This consists of several hundred acres which were left in their natural state but have been reforested with native trees. All kinds of wildlife are exhibited here in their natural setting.

Lake Springfield is one of the few lakes located in central Illinois where recreational facilities have been established. The water department feels it has contributed much to the recreational life of the community and has improved its relations with the people in the surrounding area. The Lake Springfield development provides an outstanding advertisement for the department.

Edward S. Hopkins

Prin. Assoc. Engr., Bureau of Water Supply, Dept. of Public Works, Baltimore, Md.

A contract was signed between the city of Baltimore and the League of Maryland Sportsmen in 1946 which permitted fishing in the Prettyboy Reservoir from boats owned by the league and rented to individuals. The Prettyboy Reservoir is a reserve lake containing 20 bil.gal. of storage, which feeds directly into the active, 23-bil.gal. Loch Raven Reservoir. In addition, supervised fishing from the reservoir banks was also permitted under the contract. This was a reversal of the time-honored policy of the Bureau of Water Supply, which had forbidden fishing in these reservoirs.

In the contract the League of Maryland Sportsmen was designated as the agent of the city in the operation of the fishing program and was required to provide adequate personnel to insure public safety and prevent pollution of the water. All boats were the property of the league. Any permanent improvements erected were to become the property of the city. It was expressly stipulated that the areas would remain under the control of the city and under the jurisdiction of the Bureau of Water Supply. All action taken by the organization would be in the name of, and as agent for, the city.

Sanitary Regulations

Under this agreement, operations were initiated on a comprehensive scale in June 1947. A state license was required plus a daily fee for the use of the area, and a rental charge was made for fishing boats. All receipts were handled by the league. A boat harbor was established at which point were also located the management office (housed in a trailer) and permanent privy houses for both sexes. This location was selected by the Bureau of Water Supply. The League of Maryland Sportsmen was directed to:

> Provide separate toilet facilities for each sex having not less than five spaces inclusive of urinals for men and two spaces for women. The toilets shall be of the "Kaustine" type, with watertight and flyproof construction. The excreta contained therein shall be periodically removed by pumping into tight containers and disposed of by burial in areas to be approved by the State Department of Health and the Baltimore County Health Department and distant from the waters of the Reservoir. The privy house shall be sprayed monthly with a 3 per cent solution of DDT in kerosene.
>
> Secure a sufficient number of watertight receptacles of metal construction with tight-fitting lids for the collection of garbage and trash. All receptacles shall be emptied daily and their contents burned at the close of activity each day in an incinerator provided for this purpose, to be located in the landing area. Receptacles shall be kept on unscreened racks having a height of 18 in. above ground. The racks and adjacent area shall be kept clean and periodically sprayed with a 3 per cent solution of DDT in kerosene.

Printed regulations were posted and the approved sections on sanitation were made applicable to all persons using the water or surrounding lands of the impounding reservoir. These sections read:

> *Sanitation.* Urinating or defecation into the waters of the reservoir or into any watercourse leading to it are prohibited. Toilet facilities have been provided in the landing area and shall be used when required. In emergencies, urine may be discharged on shore not

less than 200 ft. from the edge of the water or from the banks of any watercourse leading to the reservoir; defecation must be confined to the toilet facilities provided.

Bathing, wading and swimming are prohibited.

All garbage, trash, waste paper, etc., must be placed in receptacles provided for this purpose in the landing area upon return of each boat. Throwing or depositing of trash, garbage or refuse on the waters or shore of the reservoir is prohibited.

The above regulations and requirements were concurred in by the Maryland State Dept. of Health.

To further safeguard the area, in October 1947 the land adjacent to Prettyboy Reservoir was declared a game preserve by the State Game and Inland Fish Commission.

The employees of the League of Maryland Sportsmen adequately enforced the regulations. "Kaustine" toilets were installed in a properly constructed cinder blockhouse with screened doors and windows. This was located at the boat harbor. Frequent inspections by representatives of the bureau disclosed adequate housekeeping. Occasionally refuse and trash were noted, which were promptly removed, and every effort was made to comply strictly with the agreement and other sanitary requirements demanded by the bureau.

A maximum of 575 persons was reported on July 4, 1947, with a weekday average of 100 and a Sunday average of 250. Of the number of permits issued, a large proportion were obviously used for fishing from the banks since the league had only 50 boats available.

A new contract has been negotiated for 1948 which will permit fishing in both the Prettyboy and Loch Raven Reservoirs. An additional boat harbor will be erected in the Loch Raven area at a location that will provide not less than twelve days of flow through the reservoir before reaching the intake at the dam leading to the Montebello Filtration Plants. Privies similar to those at Prettyboy will be erected, and the same sanitary rules and regulations will apply to both reservoirs. This contract permits fishing from boats only, revoking the privilege of fishing from the Prettyboy Reservoir banks.

Bacterial tests of the water entering the filtration plant are made daily. Recreational use of the reservoir has not affected the total counts or increased the density of the coliform organisms. It is apparent, therefore, that, at lakes of this size, there is no sanitary basis for the exclusion of controlled fishing. The potential hazard is, however, great. Without the added safeguard of a modern, adequate purification plant, the possibility of a typhoid carrier polluting the water while fishing from a boat is ever present. This danger is neutralized by modern purification methods but would not necessarily be overcome in a supply with chlorination as the only treatment.

Evaluation

Since this discussion deals with the use of water supply reservoirs as part of a public relations program, it must be noted that, with a population approximating a million, the number of persons fishing in the reservoir is infinitesimal in proportion. An organized minority of this type, however, is extremely vociferous, and, since it is apparent that it does not create a sanitary hazard, it is expedient, practical and politic to permit fishing under controlled conditions. Should efforts be made to include the Loch Raven Reservoir area as a game preserve, it is believed that

public repercussions would prevent such action and cause the present policy permitting fishing to become objectionable. For many years the Loch Raven area has been a popular section for automobile trips through the woods, and its restriction would meet with extreme disfavor among many persons.

The public relations value of permitting fishing under these conditions in a very large city is negligible. Only a limited number of individuals are affected, the majority of the people being completely indifferent.

Charles E. Moore

Mgr., City Water Dept., Roanoke, Va.

Before discussing the policy of Roanoke, Va., on the public use of reservoir lands, it may be well to give a brief description of the conditions affecting the city water supply. The entire Roanoke watershed is practically uninhabited, with substantially all of the land owned by the municipality. The dam erected to impound the runoff waters is built to a height that will furnish the maximum supply over a three-year dry cycle. This means that, when used to capacity, the lake will regularly be drawn down materially each summer, because withdrawal will be at a maximum and runoff at a minimum. The nature of the soil, the topography and the average storm intensity are such that filtration of the reservoir water is an absolute necessity. The water supply system, though municipally owned, is entirely self-financed, the service charges being sufficient to operate the department and provide for its expansion just as if it were a privately owned corporation.

The newly constructed reservoir, created for the sole purpose of furnishing a water supply, is the only body of water readily available for a single day's outing. The question therefore arises whether public use for recreation should be allowed and, if so, to what extent.

As long as the public water works systems throughout the United States and Canada can with perfect safety treat and deliver water for domestic consumption from a source which is highly polluted, it seems preposterous under existing conditions to answer the question of public use with a flat no. Recreational facilities should be offered to the general public, but due regard should be paid to public sensitivity and to the establishment of reasonable rules and regulations.

Bathing

Generally speaking, it is the author's judgment that actual bathing and wading should be excluded. Although it is perfectly possible that even unlimited bathing by the general public would not create serious contamination in the reservoir water, the very idea produces an adverse psychological reaction in the public mind that no one seems willing to attempt to overcome. The problems of fishing, boating, hunting and picnicking remain to be settled.

Fishing

In 1947 the reservoir was open to limited fishing, boating and picnicking, and there has been considerable public demand to permit fishing subject to the local and state fish and game laws. Although this is a reasonable request, the principal purpose of the reservoir should not be forgotten. Such privileges may be freely granted, but those charged with the operation of the water supply system should reserve the right to stop fishing at any time if the natural fish life balance appears to be upset, resulting in undue algae growth and

the overabundance of frogs and the like. The water management should be empowered to keep the restrictions in force until the fish life balance has been restored to a point where fishing by the general public can be resumed without detriment to the quality of the water impounded.

Boating

Boating may be enjoyed for its own sake or as an adjunct to fishing. If the fisherman is to be permitted the fullest enjoyment of his sport, under the conditions mentioned above, it seems only fair that some restrictions should be placed upon boating as a pastime. Therefore, boats propelled by motor, either inboard or outboard, should be limited in horsepower so that their use does not entirely ruin the sport for the fishermen. The maximum horsepower that may be used will depend on the shape and size of the water surface in question. No boat should create such a wave action that, regardless of its position and course, it would seriously interfere with fishing.

Remembering the reservoir will not normally have an overflow in the summer, the right to discontinue the use of motorboats at any time should be a part of the conditions of the privileges granted the public.

Excessive oil film on the water surface costs money and hurts everyone—the fisherman, the picnicker, the boat enthusiast, the plant operator and the fish as well. Of more importance than all of these combined, however, is the fact that tastes and odors may occasionally result, causing some people to resort to untreated water sources. This should never be allowed to happen.

The type of boat permitted, with or without motors, should be subject to regulation whether the city furnishes and owns all of the boats or whether individuals are allowed to place their own boats on the water. For safety's sake, all metallic boats, and those easily tipped over, should be equipped with air chambers; and all boats of any nature should be required to provide the equivalent of a life preserver.

Sailboats at present are permitted at Roanoke, but, while it is true no serious accidents have occurred, the body of water is narrow and is located in a mountainous area, making it subject to sudden and violent windstorms. Because too few persons possess sufficient knowledge of sailing craft to pilot them with any degree of safety, such boats should be prohibited.

Hunting

Hunting is permitted by state law for a relatively short season, during which boating and fishing are the least desirable. But even so, this sport should be permitted only in the wooded area away from the reservoir, so that the travel of stray shot is reduced to a minimum. Rifles and pistols should be prohibited, except perhaps on a specially constructed range and only under supervision.

Hunting at or over the water for water fowl or any other game should not be allowed. No one can hope to convince some people that the dead duck they saw at the dam would not be a source of danger to them or the water supply generally.

Hunting at Roanoke is, in fact, prohibited, but this is due to the present scarcity of game. It is likely that an area of approximately 12,000 acres will be made a game sanctuary, and, with other recreational facilities being permitted, there is, of course, the proba-

bility of a public demand for at least a limited hunting season in the not-too-distant future.

Picnicking

During the summer of 1947 picnicking formed a natural part of the boating and fishing activities. As time goes on, it is conceivable that picnicking could become, so far as the number of people in any one day is concerned, the major activity. In that event, the need for sanitary facilities would materially increase. The reservoir area, however, is not the only place suitable for this type of recreation, so that the demand for such privileges cannot be made on the basis that there is no substitute.

It would seem proper to discourage picnicking for economic reasons, if for no others. At present a fee is being charged for fishing and boating, but no charge is made for picnicking privileges alone. It is not intended to be mercenary, but it should not be forgotten that the municipally owned water department is entirely self-financed. There can be no valid excuse for paying the costs of supervising recreational activities, or the capital investment for such facilities, out of water revenues.

The over-all answer seems to be that under existing conditions at Roanoke—the presence of a modern filtration plant, the right of the department to curtail or suspend recreational pursuits when necessary, and the adoption and enforcement of reasonable rules and regulations—the general public may be permitted to enjoy some recreational pursuits. No expensive permanent facilities should be provided because, in time, usage will cause a greater and greater drawdown of the reservoir in summer, making it more susceptible to contamination and less desirable as a playground.

Harry B. Shaw

Deputy Chief Engr., Washington Suburban San. Com., Hyattsville, Md.

Because the recent reports of the National Parks Committees for England and Wales and for Scotland (1, 2) affect the location and control of water catchments in those countries, the documents are of interest and value in the consideration of the subject being discussed by this panel.

The British committee was appointed in 1945 by the Minister of Town and Country Planning "to consider the proposals in the Report on National Parks in England and Wales of May 1945 as to the areas which should be selected as National Parks and to make recommendations in regard to special requirements and appropriate boundaries;" and to report on "the measures necessary to secure the object of National Parks" (1).

In 1946 the scope of the committee was widened to consider the measures necessary to provide for footpaths and access to the countryside of all of England and Wales. This is a very far-reaching project, involving rights-of-way, except for vehicular traffic, over both land and water and access to the wild or uncultivated areas of both countries.

Primary Objectives

The British committee report (1) states definitely that the first consideration is the preservation of the landscape and the facilities for its enjoyment. It points out that water catchments are among the developments which may interfere with the primary objectives

of the national parks and that such projects should be allowed within the parks "only under proven national necessity; and that even then greatest care must be taken to minimize their detriment to the landscape."

According to the report, "The broad objectives of planning in National Parks will be the protection, and to a lesser extent the improvement, of their landscape beauty, and the preservation of features of natural, architectural or historic interest, for the benefit and enjoyment of the nation. The achievement of these objectives will entail: (1) the control of all new development and use of land; (2) the removal or mitigation of existing disfigurements or undesirable development and the discontinuance of unacceptable uses of the land. The first of these functions will be directed to safeguarding the future of National Parks, the second to undoing the mischief of the past."

The committee explicitly recommends that not only should the details of any future water supply developments within a national park require the approval of the agency controlling the park (a Park Committee appointed by the Minister of Town and Country Planning is suggested in the report) but any project of a water utility already authorized by law should also be subject to the Park Committee's approval. Moreover, any existing water catchment project which the Park Committee feels interferes with the proper use of the park or disfigures the landscape would have to be modified or removed to suit the committee. The utility would be compensated from the national parks budget in such cases and appeal could be made to the Minister of Town and Country Planning.

Furthermore, the report states: "We presume that all draft Bills or Orders seeking authority for water catchment undertakings in National Parks will be referred to the National Parks Commission, . . . and that the Commission will be enabled to make objection to the construction of a reservoir or any other work, on any site within the boundaries of a National Park, if in their view such construction is undesirable or unjustifiable. Where water undertakers seek powers, as we understand they will increasingly do, under the Statutory Order procedure of the Water Act, 1945 [*see* Reference 3], we assume that the National Parks Commission will be able to make representations to the Ministry of Health, as the sponsoring department, objecting to the granting of an Order.

"We do not wish to imply by the two preceding paragraphs that the Commission would offer uncompromising opposition to any reasonable demand for the impounding of water in any National Park; at the same time we wish to ensure that they should have an opportunity to raise objections, and to require thorough consideration of possible alternative schemes not involving the Park, or where a scheme is broadly acceptable, to make representations as to the siting, design and appearance of the proposed works."

In essence, therefore, the committee recommends that the location and control of water catchments in the national parks be subject to the veto or approval of the park authorities, who might be overruled by a council of cabinet ministers should the conflicting interests of more than one department of the government be involved.

The report would appear to recommend that the National Park Commis-

sion be given final authority over the control of the parks in which water catchments are located, the primary considerations again being the conservation of natural beauties and the fullest recreational enjoyment of them by the public. In this connection the limitation of hikers' access to water catchment areas presents a serious problem.

In addition to the establishment of the twelve national parks listed in Table 1, the report also recommends that 52 "conservation areas" which require special treatment be established. Although the committee seems to feel that the general principles of the national park plan should apply to these conservation areas, the report indicates that provision should be made for additional water supplies in certain conservation areas and that the controlling body of an area will have to give attention to "the location and pureness of reservoirs and water works."

Parks and Water Catchments

A very good idea of the relation of water catchments to the proposed national parks is given in the excerpts below.

Lake District. "Much has been heard recently of water catchment in the Lake District, which is indeed an obvious source of water, and has for many years been exploited for the benefit of large and populous areas, including West Cumberland and the City of Manchester. The character of the Thirlmere valley and more recently of Mardale has been altered in the process, not for the better. The fields in the dale heads are submerged; the farm land is sterilised; homesteads are ruined; conifers are usually planted on the hillsides; the dams themselves are never quite in place among the fells, and the inevitable rise and fall of the water level destroys the natural harmony of the foreshore by introducing an unsightly belt of mud, bare gravel or bleached rocks below the high water line. Boating and bathing are forbidden, and the few remaining farmers may not keep cattle or take in visitors. A proper determination to save West Cumberland from reverting to depression, and to provide adequate water for other urban and rural areas, has led to far-reaching proposals for the further damming of lakes and valleys. Ennerdale Water is the latest victim. There is no more difficult problem in the Lake District than to supply water for the reasonable needs of surrounding areas, without destroying the native beauty and essential character of the country. The powers and procedure suggested in paragraphs 133–137 of Chapter VI should be strictly and wisely applied in order to ensure that the right balance is struck. A large part of the district should certainly be immune from further damming."

TABLE 1

Proposed National Parks

Park	Approx. Area *sq. mi.*
Lake District	892
North Wales	870
Peak District	572
Dartmoor	392
Yorkshire Dales	635
Pembrokeshire Coast	229
Exmoor	318
South Downs	275
Roman Wall	193
North York Moors	614
Brecon Beacons and Black Mountains	511
Norfolk Broads	181

Peak District. "Another increasing threat is that of the catchment and im-

pounding of water. The near-by cities already draw vast supplies from this area and others are now looking to its few untapped watersheds. A dozen large reservoirs now cover much land that was once fertile and lovely, resulting in the loss of numbers of farms and the eviction of their inhabitants—the loss too of villages where visitors would have found much needed accommodation under true country conditions. Moreover the fear of pollution has led to curtailment of popular access to the catchment areas. Many schemes have been executed with little appreciation of the finer landscape values, particularly in the treatment of fencing, roads and viaducts, and in the formal planting of conifers, where native hardwoods might have gradually made a more natural setting to these artificial lakes. The time has come to consider whether this region should suffer further intrusion of this kind. It will certainly be essential that the National Parks Commission should be consulted, and their advice given full weight, on any new proposals for water catchment within the National Park."

Dartmoor. "Several large reservoirs already exist on the Moor. The two largest at Fernworthy and Burrator have added an element of interest to an area which is lacking in natural lakes. If scientific methods of water purification could be brought into play so that these reservoirs could be opened to popular access, and to boating and fishing, they would make a great contribution to the recreational value of the National Park."

Yorkshire Dales. "Crosscountry rambling is, by long-established custom, unrestricted on the uncultivated land of about three-quarters of the area. In the other quarter—the gritstone country—there is a varying amount of restriction, on account both of grouse moors and of water catchment. It is essential that this restriction should be removed, and it may not be easy to achieve this quickly, though the problem is less severe here than in the northern part of the Peak District."

North York Moors. "Another serious threat has come from the proposal of the city of Hull to construct a large reservoir in Farndale, with smaller ones in Bransdale and Rosedale. Farndale and Bransdale are two of the loveliest of all the valleys. It is greatly to be hoped that alternative sources of supply will be found elsewhere."

Brecon Beacons and Black Mountains. "The Brecon Beacons area is a valuable source of water supply for South Wales. Catchment areas, serving some eleven important water authorities, cover about 44,000 acres of the National Park, and there are already ten reservoirs within its boundaries. Several of these are enclosed by formidable black spiked railings, while their stone dams, pumphouses and asphalt paths, and the formal blocks of fir trees on their banks are most unhappily out of harmony with their setting of mountain solitude. Some improvement in their appearance might be effected with the expert guidance of the Commission's architects and landscape advisers. At the same time all proposals for new reservoirs—a number of which are already projected—should be very carefully scrutinised."

The Broads. "The main intake of part of the water supply of Great Yarmouth is on the river Bure above Horning, with Ormesby Broad as a reserve source. Both sources are sub-

ject to salt contamination and organic pollution. Moreover this use of Ormesby has made it necessary to discourage boating on the Flegg Broads. Pollution from sewage presents a further problem. Works are in progress which will eventually eliminate contamination from Norwich, but untreated sewage from Yarmouth is carried far inland by the tides and there is also sewage from boats and riverside dwellings. These problems, although primarily the concern of the local authorities, are not without relevance to the holiday use of the Broads, in which the National Parks Commission will have direct responsibility."

British Management Attitude

Because conditions in the United Kingdom differ from those generally prevailing in this country, the attitude of British water works officials might likewise be expected to be somewhat different from that of their American counterparts. For example, John Stewart (2) of Glasgow, Scotland, in commenting on the report of the Scottish National Parks Survey Committee, states: "I have had the opportunity of discussing the Survey Report with several [water engineers], and I find that they take a gloomy view of such a suggestion; indeed, nowhere do I find any responsible person, lay or professional, who is in favor of granting access to the gathering grounds, except under the most rigid control, amounting almost to exclusion. . . . I would limit access to watersheds entirely to those responsible for the care and protection of the water supply—and most [water officials] would go a long way with me. . . . A water supply must be as well protected and controlled as possible, so that it is as pure as human effort can make it."

Stanley D. Canvin (2), also of Glasgow, in his discussion of Stewart's paper says: "Catchment areas are of paramount importance to a water undertaking, but they are not the whole of the undertaking. Because of the purity of the supplies from them, consequent upon their acquisition and vigilance in their upkeep, especially in Scotland, elaborate and expensive mechanical or artificial works of filtration are seldom required. But in the event of any risk of pollution, such filtration would be necessary in many places where at present none is called for. Now filtration and chlorination are very costly and are not foolproof, both depending upon human factors for their efficiency. Capital cost of filtration works would be a major issue to any authority at present not requiring them. New maintenance charges would be a very serious added obligation. Large areas of land would have to be made available near the works and this alone would present great new problems. To give only one example, in Glasgow—where we do not filter our Loch Katrine supply—if filtration became necessary through pollution, all our present gravitation supply of 80 mgd. would have to be pumped. Think what problems, financial and engineering, such new departures would entail. We shall be told modern science can eradicate slight or serious pollution and contamination. That, of course, is correct. But a water supply so filtered and chemically treated is a trend towards synthetic water. The risk of any action that would change a naturally pure and wholesome water supply to a synthetic one is a retrograde action."

Conclusions

As surface water supplies in the United States almost invariably require filtration or treatment of some kind prior to being distributed to the public, so great a degree of apprehension need not be felt toward the controlled use of watersheds by the public. The author is thoroughly in accord with the idea of making greater recreational, agricultural and silvacultural use of watersheds when this can be done under proper conditions without jeopardizing the safety of the water supply.

The excerpts concerning water catchments in the proposed national parks bring out certain facts that American water management might well bear in mind, such as unnecessary restrictions on fishing, boating and the keeping of livestock; the treatment of roads, fences, bridges and other works with relation to the landscape; and the planting of conifers where hardwoods would produce a more natural setting. The planting of conifers on American watersheds has surely often been overdone.

The report of the National Parks Committee is provocative of thought which should help water works men realize that, despite the importance of their work, they must adjust their operations to fit in with, and be an integral part of, the activities of the whole community.

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Foaming and Carry-over in Boilers

By R. W. Seniff

A paper presented on May 6, 1948, at the Annual Conference, Atlantic City, N.J., by R. W. Seniff, Engr. of Tests, Gulf, Mobile & Ohio R.R. Co., Bloomington, Ill.

THIS paper reviews some of the carry-over problems which have been encountered in the railroad field and the methods used for overcoming them. Some personal observations of the author are reported on: (1) the effect of water treatment; (2) locomotive boiler design and foam carry-over; and (3) carry-over in the absence of foaming.

The problems of carry-over in boiler operation are being minimized in one sense by the increasing utilization of diesel power. On the other hand, the control of carry-over becomes increasingly important where steam continues to be used as a medium in power production. It is possible that the gas turbine may supersede the diesel engine and nuclear energy may eventually supersede both, at least to some extent. In the present state of scientific knowledge, nuclear energy can be transferred into useful work only through the path of heat. This indicates that steam boilers and turbines may be the medium for this transfer (1).

Coal is the most abundant source of transportable energy on this continent. Its energy is also transferred into power through the medium of steam boilers. The effect of the coal-burning gas turbine on the use of steam in power production remains to be determined. The synthesis of oil substitutes from coal holds no promise of a substitute liquid fuel which could compete with coal in large power plants. Most oil companies now burn coal, not oil, in their refinery power plants. The Steam Locomotive Research Institute (2) is developing a coal-burning steam locomotive boiler with a new type of water-tube firebox which will operate up to 600 psi. It appears that boilers will continue to be the backbone of the nation's power, with diesel engines, gas turbines and nuclear energy used in the specialized jobs in the transportation industry for which they are particularly adapted. Carry-over from power boilers will continue to be an increasingly important factor economically because of the rising cost of coal, labor and materials and the necessity for competition with other sources of power.

Occurrence of Carry-over

The problems of carry-over from power boilers probably date from the first power boiler, because the tendency toward carry-over is present in some degree wherever bubbles pass through and escape from a liquid. The difficulty of keeping the liquid and solid constituents of bubbling solutions where they are desired and of getting satisfactory clean vapors is not confined to boiler operation. Carry-over by foaming may be encountered in the kitchen when rice is boiled; it may also occur without boiling and without foaming in the battery shop when acid batteries are charged. It is encoun-

tered in industrial processes where bubbles pass through either boiling or cold liquids. Whether it is a problem or not depends upon the quantity and nature of the material carried over and its effect upon the processing or use of the gas which carries it. Sometimes, as in sulfuric acid concentrating plants, the carry-over is the valuable constituent of the gas and constitutes an economic loss if it is not recovered.

It is well to remember, therefore, that carry-over may occur from a number of causes in many liquids, at pressures varying from partial vacuum to high and at any temperature above the freezing point of the liquid; moreover, a single bubble can produce carry-over. Many of the phenomena readily observable at atmospheric pressure and temperature are similar to those which occur in steam boilers.

Foaming

Foam is probably the oldest recognized source of carry-over. Its mechanism is not greatly different from the boiling over of a pan of rice on the kitchen stove. Probably one of the earliest successful approaches to the foam carry-over problem was made by some long forgotten, very observing farmer while boiling down maple sap in open kettles at his sugar camp. He found that a piece of raw fat meat, suspended by a string a few inches above the surface of the boiling sap, caused the foam to subside whenever it touched the fat. This was probably the first automatic foam control.

Later emulsified castor oil was used by dispersing it in the feed water to control foaming in locomotive boilers. This was recently superseded by the synthetic waxlike polyamides (3, 4) employed in much the same manner as castor oil. The polyamides have the advantage that they can be incorporated in a powder compound for convenience in handling. They have much greater foam-destroying properties and last much longer in the boiler than castor oil. The structure of the polyamide molecule, which can be varied considerably by the methods of synthesis, has a striking effect on its foam-controlling property. It has been found effective in evaporators as well as steam boilers. There are some boiler waters, however, which will not react to any known antifoam. The author believes this is due to the character or amount—or both—of the "nascent" sludge formed as the feed water enters the boilers, because waters low in such sludge appear to react more readily to antifoams.

Partial blowdown, commonly called "blowoff" in the railroad field, is the oldest and most universal practice followed for the control of foam carry-over from steam boilers. It has been the author's experience that a given water supply in a given boiler, operated at full rating in the presence of nascent sludge, will cause foam carry-over with mathematical precision when a certain concentration of dissolved solids is reached in the boiler; the amount of carry-over is equivalent to the amount of blowdown required to maintain the concentration at which the boiler starts to foam. This has been substantiated by service tests in which the boiler was allowed to foam over. The pounds of boiler water carried over as foam equaled the calculated blowdown requirement. This concentration varies, of course, with the kind of water used and the characteristics of the boiler. A common minimum concentration at which locomotive boilers foam in the presence of nascent sludge is 2,500 ppm., although this figure may vary as much as several hundred per cent up-

ward with different water supplies. Many railroads predicate partial blowdown instructions upon data of this nature obtained from boiler performance tests over the line-of-road. The carry-over problem is probably more difficult to control in locomotive boiler operation than in any other type of boiler service. Stationary boiler operators can imagine the magnitude if they envision using six to eight different feed waters, all of different characteristics, in a 24-hour period, with load variations of 0–100 per cent steam demand in a matter of seconds.

Various types of continuous as well as automatic blowdown devices have been developed to improve partial blowdown procedure and to remove the guesswork frequently involved in manual manipulation of the blowoff cock by engine crews. One such rather widely used device (5), involving an electrode located in the steam space above the water level in the boiler, activates a signal and opens a blowoff cock when foam contacts the electrode. Although more complicated, it resembles the farmer's piece of fat meat in that foam initiates the reaction. The analogy has been carried further, experimentally at least, by connecting the electrode to a small pump which injects antifoam. The use of electrode metals which dissolve in the foam under the influence of electric current when foam contacts them was also tried with some success but no progress has been made beyond the experimental stage.

Various types of steam separators, somewhat similar to those used in stationary boilers, have been developed for steam locomotives (6). Water treatment by softening and by reducing the solids in feed water is employed to lessen the foaming tendency.

It is interesting to note that, although technicians have learned to control foam carry-over reasonably well by various means, they have been satisfied to stop just short of its elimination as an operating problem when the method for attaining it has been at hand for nearly 60 years. In 1890 Lord Rayleigh (7) reported that strong sodium chloride solutions did not foam. In 1900 Koyl (8) reported that no foaming occurred in certain locomotive boilers operating with high boiler concentrations unless finely divided solid matter was present. Koyl demonstrated this fact experimentally in the laboratory at that time, showing that boiling water containing several hundred grains of sodium carbonate did not foam until powdered calcium or magnesium carbonate was added. He demonstrated in locomotive boilers that mixing untreated with treated water increased the tendency to foam because of the hardness precipitated as sludge in the boiler. Tatlock and Thompson (9) in 1904 reported a boiler which did not foam when operated with a boiler water concentration of 31,000 ppm. Foulk (10) in 1925 wrote: "The contradictory statements found in boiler water papers concerning the relation of sodium salts to foaming can easily be harmonized. . . . Heretofore the two conditions for foam formation. (A) film production and (B) film stabilization, have not been looked upon as separable in boiler water chemistry." That was 35 years after Lord Rayleigh's observation and 25 years after Koyl's report on the foaming tendency of waters free from sludge compared to those containing sludge.

An example of an apparent contradiction is found in Handcock's report (11) in 1937 to the effect that the more sodium salts contained in a boiler run-

ning on softened water, the greater was the tendency to prime (foam) and that 3,400 ppm. was the maximum permissible concentration. He also stated that the softening of locomotive feed water invariably resulted in increased priming (foaming), especially if the water was reduced to a low degree of hardness; tests in locomotive and experimental boilers, he claimed, provided no evidence that insoluble or suspended matter was the material which caused foaming. The phrase "low degree of hardness" used by Handcock is significant, because the correctness of his statements hinges upon it. Residual hardness in the boiler feed water will produce an equivalent of sludge in the boiler. Indications are that the effect of sludge is more qualitative than quantitative, small amounts producing almost the same foaming tendency as large amounts, and that the effect of soluble salts is quantitative when nascent (freshly formed) sludge is present even in small amounts. Therefore, in water softened to a "low degree" foaming will vary with the soluble salt concentrations. In clear, completely softened water, foaming is not a function of the soluble salt concentration.

Topman (12) in 1939 reported the unusual performance on the Buenos Aires Great Southern Railway, where, with complete zeolite feed-water treatment, locomotive boilers operated without foaming, using boiler water concentrations of 73,500 ppm. Topman stated that small amounts of sludge caused foaming in these boilers and that this became immediately apparent whenever partially treated water escaped from a softening plant.

The concentration of boiler water salts and the presence of precipitate in the boiler are separable factors. One approach to the solution of the foaming problems in locomotive boilers is simply to use clear feed water of zero hardness.

The practical application of this principle is approached, but not quite achieved, with cold lime-soda softeners, as indicated by the many instances in which boiler water salt concentrations do not greatly exceed 2,500 ppm. without the use of antifoam. If the feed water's residual hardness ("potential sludge") is sufficiently low, antifoams work; the lower the potential sludge, the more effective they become, until a point of zero potential sludge is reached at which antifoams are not needed. If the potential sludge is high and cannot be reduced, the only alternative is the use of the blowoff cock to keep the dissolved solids in the boiler water below the concentration at which foaming occurs in the presence of nascent sludge.

The following is a typical example of stopping just short of complete elimination of foaming carry-over. For many years the Alton Railroad maintained a minor locomotive boiler feedwater supply at its South Joliet Yard. This water was pumped from the Brandon Pool of the Chicago Sanitary and Ship Canal, which was mostly Lake Michigan water, badly polluted with Chicago's sewage. This water was treated in the wayside storage tank with soda ash and used by a few switch engines operating at that point. Foaming was prevalent and boiler water salt concentrations greater than 1,000 ppm. could not be carried in the boilers (13). When road locomotives occasionally took water at that point, foaming delays occurred. Antifoam compounds were absolutely ineffective when used with this water. Wartime conditions sud-

denly made the station an important watering point for both switch and road locomotives. Earlier experiments had indicated that the reduction of the hardness to zero and the removal of sludge rendered the water relatively nonfoaming. The problem was how to remove all the sewage sludge economically, because traces of it nullified the antifoaming effects of treatment. It was decided that a carefully operated, activated sludge blanket type of lime-soda ash treating plant with gravity sand filters (13) would do the job. Such a plant, completed and placed in service in 1943, immediately produced the best locomotive boiler feed-water supply on the railroad and eliminated a severe wartime bottleneck.

It is significant that the boiler water salt concentration at which foam carry-over occurred increased immediately from 1,000 to approximately 5,000 ppm., with a corresponding decrease in blowdown requirements. The water entering the treating plant contained foul-smelling sewage and industrial waste of all kinds, including oil and grease. The turbidity of the raw water on numerous occasions exceeded 5,000 ppm., but the finished water was clear, bright and colorless. The odor was greatly reduced but still noticeable. The reduction of the boiler soluble salts did not account for the improvement in foam-over characteristics because the decrease was only from 487 to 432 ppm., a difference of 55 ppm. The sodium carbonate content of the feed water was practically the same for both kinds of treatment. The insoluble solids, such as sewage and oil, were reduced to zero, and the potential sludge from residual hardness was reduced from 179 to 10 ppm. The removal of the sewage sludge and the reduction of potential mineral sludge to 10 ppm. accounted for the improvement in the foaming tendency of the boiler water.

To determine the effect of each of the two types of sludge, the sewage sludge was held at zero while the hardness of the treated water was allowed to increase to 26 ppm. This resulted in reducing the concentration at which the boilers foamed from 5,000 to about 2,500 ppm., the normal concentration at which foam carry-over occurred with other water supplies on the line-of-road; in these supplies, soda ash was the only chemical used for treatment and all the potential sludge in the raw water was allowed to enter the boilers. Tests in the laboratory indicated that the removal of the 10 ppm. of residual hardness in the South Joliet feed water eliminated the tendency to foam. A zeolite softener in series after the South Joliet Plant, for the purpose of removing the last trace of potential sludge, would have produced a nonfoaming boiler water.

As it was believed that the effect of antifoam is to nullify the foam-producing effect of sludge, polyamide antifoam was again tried. (It will be recalled that the polyamides had no effect on this water before installation of the treating plant.) The result was the same as if zero-hardness water had been used. The boilers which used this water exclusively did not foam. A salt concentration of approximately 11,000 ppm. was reached in the boilers, where the 0.5 per cent carry-over which is normal to them (probably because of splash spray) maintained it at a constant value. This concentration is equivalent to 26 times the concentration of the feed water. No attempt was made to work at this concentration as

a routine practice, but advantage was taken of it by allowing switch engines to receive partial blowdown only at the engine house once each day.

To summarize: (1) treatment of the sewage-polluted water with soda ash permitted the soluble salt content of the feed water to concentrate about two times in the boiler water before foam carry-over occurred; (2) removal of the insoluble sludge, which consisted of sewage and the like, from the feed water permitted six concentrations; (3) removal of the insoluble sludge from the feed water and reduction of the potential sludge to 10 ppm. permitted sixteen concentrations; (4) removal of both the insoluble and potential sludge permitted 26 concentrations; (5) removal of the insoluble sludge from the feed water and reduction of the potential sludge to 10 ppm. (which is the condition set up under item 3 above) plus polyamide antifoam resulted in duplicating the effects obtained from condition 4 just mentioned. The problem of eliminating the foam carry-over tendency therefore reduced itself to the economics of using antifoam with clear feed water of very low hardness or of reducing the feed water to zero hardness.

Boiler Design and Carry-over

It is well known that boilers of different designs vary in their tendency toward carry-over. Since most of the causes are obvious and well known, a boiler performance will be described in which the absence of foam carry-over appeared to be the result of an unusual combination of design and proportions. This assumption is based upon a series of road-service tests of several such boilers of the same typical design but of different proportions. They were equipped with electrodes for indicating the foam height within the boiler.

The first of these boilers was built by the Baltimore and Ohio Railroad and put into service on the Alton Railroad in 1935. It was a passenger locomotive known as the J1 (14) and was equipped with the Emerson water-tube firebox operating at 350 psi. It possessed remarkable freedom from carry-over and could be operated at boiler water salt concentrations of 6,000 ppm. in spite of the fact that its steaming capacity was low compared to the steam demand. Conventional boilers in the same service foamed at a concentration of about 2,500 ppm. (The feed waters used had residual hardness and consequently produced sludge which caused the dissolved solids concentrations to be the measure of the foaming tendency.) A little later the V2 was built and put into service. The firebox design and boiler pressure were the same as in the J1, but the proportions of the boiler were a little different. It foamed over at a slightly lower concentration. The V2 was followed by increasingly larger boilers and the foam-over tendency increased slightly with each new model until it was the same as for a conventional boiler with a standard stay-bolted Stevenson type of firebox and a boiler pressure of 200–225 psi. It appeared that as the ratio of the heating surface of the water tubes to the fire tubes decreased the foam carry-over tendencies increased. A study of the foam carry-over characteristics of this series of boilers would be a good preliminary to the design of a new type. It is believed that the rate of steam generation in the water tubes and its effect on circulation may be the important factors contributing to the unusual performance.

Nonfoaming Carry-over

Carry-over in the absence of foam may result from several causes. One is the vaporization of boiler water salts and the other is mechanical entrainment.

Morey (15) reported that certain minerals found in nature bore evidence of having been deposited directly from the vapor phase, and he suggested that steam turbine blade deposits might have a like origin. According to Straub (16), at higher steam pressures silicic acid leaves the boiler as a vapor and not as the result of mechanical entrainment. The troublesome insoluble type of turbine blade deposits are principally crystalline silica and are believed to have crystallized directly from silica vapor in the steam. Straub presents experimental data sustaining this theory and offers suggestions for the prevention of this type of deposit.

Carry-over by mechanical entrainment may result from: high water level, erratic throttle and reverse lever operation on steam locomotives (commonly called "priming" by railroad men in the United States); splashing; poor boiler design (now rare); excessive steam demand; and a spray and foglike ejection from the water surface which the author has called "aquaglobejection" in order to have a specific name for the phenomenon.

Aquaglobejection

Straub (16) states: "The water-soluble deposits found in the turbine are in general the result of mechanically entrained boiler water carried in the steam. At steam pressures below 2,400 psi. the salts present in the boiler water are not appreciably soluble in saturated steam."

The author (17) reported experiences with one troublesome kind of mechanical entrainment which interfered with steam locomotive operation, and described the method used for overcoming it. This type of carry-over undoubtedly occurs under favorable conditions in most boilers—locomotive, marine and stationary—as well as in evaporators. It had previously been referred to by various writers as "mist," "spray" or "fog." It was sometimes not made clear whether the cause of the "fog" was condensation or ejection. In 1927, at the time this type of carry-over was first recognized as an operating problem in locomotive boilers, very little was known about it. After some effort it was reproduced in a laboratory test boiler, where it could be observed through sight glasses by using a special lighting technique. Spray was observed from bursting foam bubbles, but the droplets were large and most of them fell back into the water. These were called "foam spray" after examination revealed that they came from the shattered upper portion of the bubble films under foaming conditions. With nonfoaming boiler water, large droplets were observed being ejected, not from the upper part of the bursting bubble film, but from the surface of the water immediately after the bubble burst. Where the surface of the water was relatively quiet, the droplets were ejected straight upward with considerable force. The reason, of course, is that in the absence of foam much of the bubble is below the surface of the water at the time of the rupture, and, upon the sudden release of pressure, the surface tension of the water makes the depression left by the bubble behave as if a pebble had been dropped

into the water causing a droplet of water to be ejected upward. Some boiler waters, however, appeared to boil very smoothly in the test boiler with no foam layer or visible ejection, but carry-over was found in the steam. To study this more closely, a lighting technique was devised to approximate the effect observed when a beam of bright sunlight shines through a darkened room revealing ordinarily invisible dust particles in the air. The room housing the test boiler was darkened and a strong beam of light was projected, through an observation glass in the back of the test boiler, above the water level and at an angle of between 10 and 45 deg. to a similar window on the opposite side of the boiler. When the steam was observed against this strong back-lighting at the proper angle, it possessed a foggy appearance. Careful examination of the water surface with similar lighting disclosed that the source of the fog was the same as that just described for the larger droplets, but the small drops originated from depressions where small bubbles had existed.

At about this stage, the discussion of the phenomena became clumsy because there were no names to identify them clearly. The fog was not fog—and the mist was not mist—because it was not condensed from vapor; the droplets were not drops, because they were moving upward and not dropping. The term "effervescence" has been used, but this refers to the evolution of bubbles, not drops. The drops produced were actually ejected globes of water, so they were called "aquaglobes," and the phenomenon "aquaglobejection." Globejection is therefore the result of effervescence or boiling. At low steam velocity in the boiler, the aquaglobes classified themselves into two broad classes: those which fell back into the water because of their large size and those which remained suspended in the steam like dust in the air. The former were termed macroglobes and the latter microglobes. The production of aquaglobes occurred at boiler water concentrations below that at which a foam layer is formed. Gas in the feed water, especially carbon dioxide, increased their ejection under such conditions. More microglobes were ejected where the turbulence of the water surface was slight.

It was believed that microglobes might be the cause of water-soluble turbine blade deposits encountered in central power stations. Studies were made to approximate the size of microglobes and their boiler salt content. It was estimated that their diameter was on the order of atmospheric fog or cloud particle diameters, which reach a size of 0.04 mm., because it was observed that the microglobes floated in quiet steam as well as in air. A 325-mesh screen, having openings of 0.043 mm., was placed in the path of steam containing microglobes moving at the low velocity of approximately 10 in. per minute. Microglobes readily passed through this screen.

A microglobe with a diameter of 0.04 mm. has a volume of 3.35×10^{-5} cu.mm. and a weight of approximately 3.35×10^{-5} mg. If ejected from boiler water having a concentration of 1,000 ppm., it would contain about 3.35×10^{-8} mg. of boiler salts. If dried, it would produce a particle of boiler salts having a volume of 1.5×10^{-8} cu.mm. which, if round, has a diameter of about 0.0031 mm. Approximately thirty billion of these particles would weigh 1 g.

The ease with which microglobes are transported was demonstrated in an experiment where water containing merthiolate was used for their production. The microglobes were discharged into the atmosphere of a room 30 × 40 × 20 ft. for one hour. Air samples were taken in the room at the furthest point from the apparatus by drawing the air through a filter paper for one hour and examining it under an ultraviolet light. Unmistakable evidence of merthiolate fluorescence was disclosed.

A similar experiment was the duplication of the above phenomena by using S.A.E. 40 lubricating oil at 160°F. and causing air bubbles to burst from its surface. The ejection of oil droplets, invisible except in strongly beamed back-lighting, was very violent. The experiment demonstrates the universality of this kind of carry-over, which apparently can be expected wherever a bubble bursts at a liquid surface, whether in a boiler, a beaker, a storage battery, an evaporator or a "Waring" Blender.

The prevention of carry-over of microglobes by removing them from the high-velocity steam leaving a stationary boiler involves difficulties because of the extremely small particle size. Steam washing appears to present the best possibilities for their removal in stationary power boilers. Aquaglobejection as a troublesome source of carry-over in locomotive boilers was eliminated by the simple expedient of tying a small tag on the locomotive throttle advising the enginemen when the boiler water was in a condition to produce this type of carry-over; they could then refrain from using the blowoff cock until a foam layer was attained on the boiler water surface. The foam layer method does not appear desirable for stationary boilers. It seems that there is less aquaglobejection from smoothly boiling water where the entire surface is covered with froth than from surface areas where the bubbles burst directly from the solid water surface. In the test boiler, globejection appeared to be more active at low steaming rates than at higher ones. Some consideration might be given to this approach to the problem. Perhaps a boiler working at a low steaming rate might conceivably cause more of this type of carry-over than when working at a higher rate.

Summary

When active sludge is present in a boiler, the foaming is a function of the dissolved salt concentration. The effect of sludge on foam is more qualitative than quantitative. It appears that foam carry-over can be controlled by both mechanical and chemical means and that the relative costs should determine the method used. It may be possible to design a compact boiler of high efficiency which has nonfoaming properties.

In addition to foam, silicic acid vaporization and mechanical entrainment may cause carry-over in high-pressure boilers. Steam separators, steam washing and maintenance of low boiler water concentrations appear to reduce these carry-over problems. Carry-over of foam and mechanical entrainment are problems in evaporators and boilers in general. Aquaglobejection can be reduced by maintaining a foam layer on the water surface, but this is, at best, only an expedient. It does not appear to be practical in stationary boilers, and in locomotive boilers it conflicts with foam control methods involving high

boiler water concentrations. A more practical solution for the control of aquaglobejection is desirable.

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Water Problems in Diesel Locomotive Operation

By M. A. Hanson

A paper presented on May 6, 1948, at the Annual Conference, Atlantic City, N.J., by M. A. Hanson, Asst. Engr. of Tests, Gulf, Mobile & Ohio R.R. Co., Bloomington, Ill.

THE water problems encountered in diesel locomotive operation may be divided into two distinct classes: problems of the engine cooling system and problems of the steam generators used for train heating. Each will be considered separately.

Locomotive Cooling Systems

The various diesel locomotives in common use vary rather widely in the design of the cooling system, but all of them have this in common: the cooling water comes in contact with a considerable number of dissimilar metals. If satisfactory life and service are to be obtained from these locomotives, the cooling system must be kept reasonably free from corrosion, scale, sludge and oil. This is necessary since corrosion results in the actual loss of metal. Corrosion can produce complete engine failure by developing leaks so that the cooling water cannot be retained, by leakage of cooling water into the crankcase and by fracture of the engine frame because of stress corrosion.

Corrosion products, sludge, scale and oil will reduce the efficiency of heat transfer and cause overheating of the engine. This tends to increase the rate of oil breakdown, to produce engine lacquer, to stick piston rings and to corrode bearings, thus increasing maintenance costs.

Severe deterioration of the cooling system can occur with rapidity even in as short a time as a few months. Figures 1 and 2 show portions of a cooling system deteriorated to the extent of requiring a major overhaul of the engine after eighteen months' service. Figure 3 illustrates a radiator section plugged with corrosion products in a year's time.

Figure 4 illustrates the corrosion of an aluminum corrosion-resistant cooler casing after eight years of service in a passenger unit. During most of this period the water conditioning was good, although for the first two years the control was quite erratic.

A typical illustration of cavitation or erosion corrosion of a cylinder liner, which resulted after two years of service, is shown in Fig. 5. On the other hand, Fig. 6 shows a set of cylinder liners in excellent condition after five years' service.

Although not directly a water problem, the lodging of asbestos gasket material in the radiators and oil coolers can also reduce the capacity of the cooling systems. The corrective procedure is obvious—namely, care in the application of gaskets to make certain they fit properly and do not overhang into the water passages.

Corrosion Control

No water is suitable for use in a diesel locomotive cooling system without treatment for corrosion prevention. The complex metallic equipment found

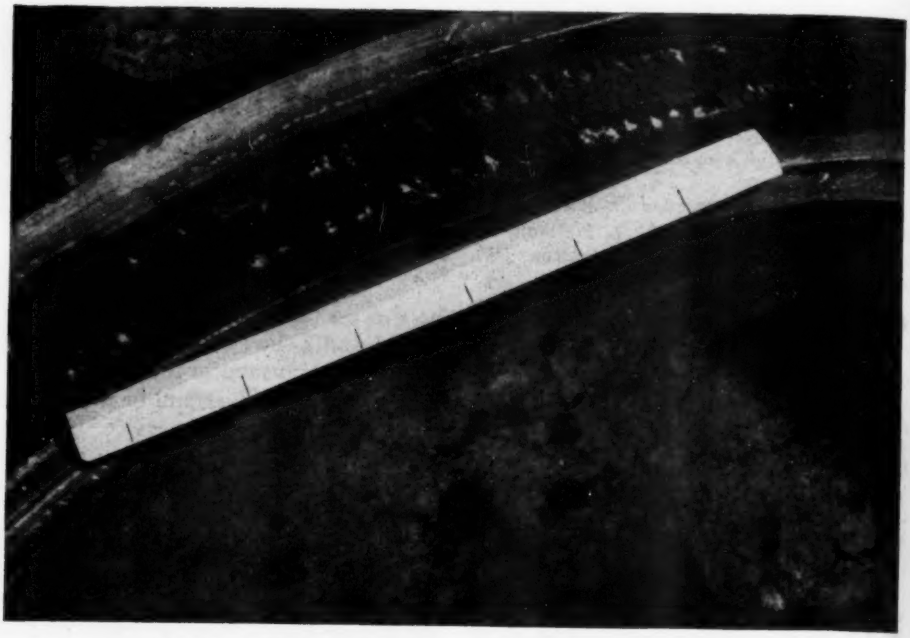

FIG. 1. Corroded Cast-Steel Ring and Cylinder-Head Seal

FIG. 2. Stress Corrosion Crack Between Retainers

in the locomotive cooling system is extremely susceptible to galvanic and concentration cell corrosion. Most commonly, the metals found in contact with the cooling water are: cast iron, cast steel, low-carbon steel plate, brass, bronze, copper, solder and aluminum or aluminum alloy. There are areas of high velocities subject to cavitation corrosion and also capillary openings of very low velocity. Since the cooling system is vented to the atmsophere, the cooling water is free to dissolve oxygen from the air. This combination of factors makes the complete prevention of corrosion quite difficult.

One major locomotive builder has recently eliminated the use of aluminum because of the extreme difficulty of passivating it. Another builder uses a relatively corrosion-resistant aluminum alloy. These are steps in the right direction.

The actual water evaporated by the locomotive unit is relatively small, frequently not exceeding 5–10 gal. per 1,000 engine miles, but the loss of cooling water may be considerable because of leaks, overfilling of the system, charging with steam at layover periods to prevent freezing, and draining for miscellaneous engine repair. This loss is an economic limiting factor in the use of a corrosion inhibitor, as the usual capacity of the system is 190 to 300 gal. Control difficulties are also increased.

The most effective corrosion inhibitor known to the author is an alkaline chromate used with water of low total dissolved solids content and a pH value adjusted to 8.5–9.5. Scale-free surfaces are required for the optimum protection. The concentration of chromate necessary is open to some debate; perhaps 500 ppm. is reasonably adequate if always maintained, but, for the sake of a margin of safety, a considerably heavier dosage is indicated.

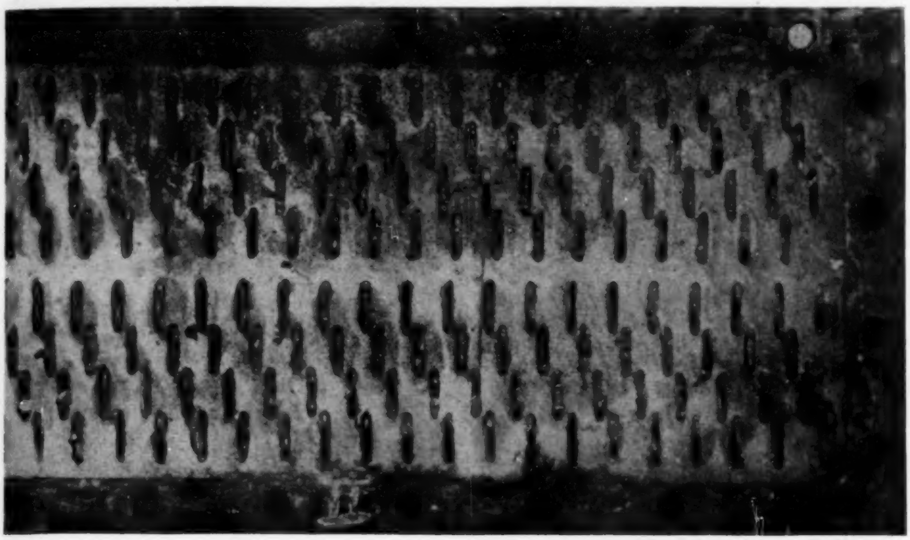

Fig. 3. Radiator Section Plugged With Corrosion Products

Sludge and Scale Control

Since the volume of cooling water added to the system is frequently of considerable magnitude, scale and

sludge can accumulate quite rapidly. To prevent this from occurring, low-hardness water is required. It may be secured by distillation, demineralization or zeolite or lime-soda treatment. The type of treatment selected is dependent upon the initial quality of the water, the volume required and the facilities available.

Oil Contamination Control

The prevention of leakage of lubricating and fuel oil or combustion products into the cooling system is primarily a mechanical maintenance problem,

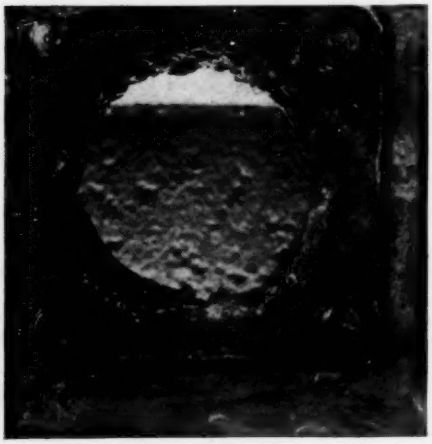

FIG. 4. Corroded Aluminum Casing

which can be met by adequately tightening head studs, renewing corroded parts where leakage could occur and changing head seals, gaskets and the like as frequently as experience has shown it to be necessary.

The thorough cleaning of an oil-contaminated cooling system is rather difficult. It is usually done by adding an alkaline type of cleaning compound fortified with a wetting agent, in sufficient concentration to give a maximum pH value of 10.5 to the cooling water; the engine is run until it is warmed up to at least 165°F., and this is followed by draining and flushing with clear water.

Summary of Recommendations

It is believed that the optimum cooling system conditions will be secured by following the procedure listed:

1. Using waters of low total dissolved solids content, with a hardness not to exceed 10 ppm.—preferably distilled or demineralized water.

2. Maintaining 1½ lb. of sodium chromate per 100 gal. of water in the cooling system.

FIG. 5. Cavitation Corrosion of Cylinder Liner

3. Adjusting the pH value to 8.5–9.5.

4. Analytical control by a competent water chemist at least once each week.

5. Draining, cleaning, flushing and making necessary repairs if oil or combustion-product contamination occurs.

6. Thorough inspection of the cooling system at overhaul periods to ascertain whether the desired results are being accomplished.

Steam Generators

There is only one type of steam generator on diesel locomotives in common use on American railroads—the Clarkson steam generator (Fig. 7). Since the water conditioning required by a steam generator is affected by its design, this paper is limited to the consideration of the Clarkson type only.

These units are forced-circulation, continuous-water-tube, oil-fired, forced-draft, electric-ignition, high-pressure provided for the flow of flue gas between the layers of the coils.

The combustion chamber is formed by the inner coil, and the steam generator jacket enclosing the coils acts as the breeching to conduct the flue gases to the stack.

The feed water is pumped into the inlet of the outer coil and flows through the coils counter to the direction of flow of the flue gases. A mixture of water and steam is discharged from

Fig. 6. Cylinder Liners After Five Years' Service

steam generators. Their operation is automatic, once started. On most railroads, steam generators are expected to operate for several hours at a time without any attention from the engine crews.

These generators are constructed of either two or three sets of coils connected in series to form a single tube several hundred feet long. The coils are placed one within another and are wound in superimposed layers, with two layers in each coil. A stagger is the outlet of the inner coil into a steam separator. The steam flows to the train line, and the water from the separator flows through a trap, heat exchanger, and return line to the feed-water supply tank. This water is re-used in order to conserve it, since carry-over is not an operating difficulty.

The usual operating pressure is from 150 to 275 psi., although this varies with different models. These generators develop steam pressure quite rapidly, requiring only about two minutes

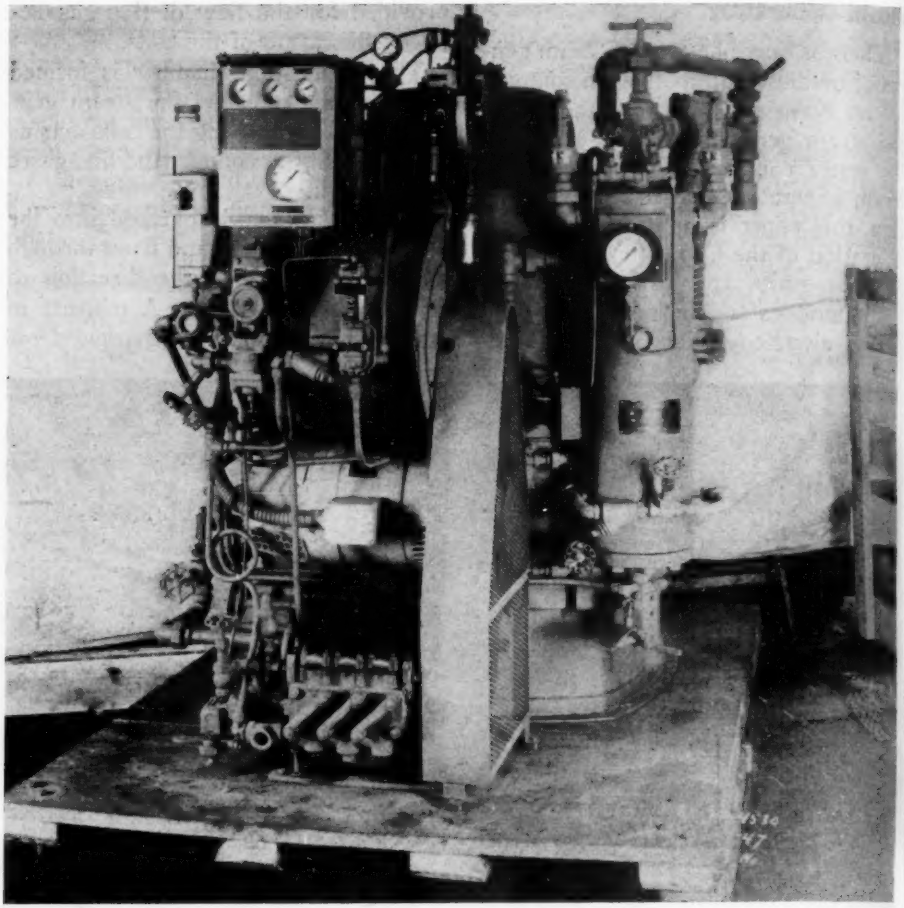

FIG. 7. Clarkson Steam Generator

from the time they are fired until a full head of steam is produced. They are available in a number of sizes, the most commonly used developing 1,600, 2,250 and 3,000 lb. of steam per hour. The thermal efficiency of a generator in good mechanical condition is as high as 78 per cent.

The water conditioning required for the satisfactory operation of these units is more critical than that needed for a conventional boiler of the same pressure range.

When these units were first placed in service, practically all railroad users relied upon a small key-regulated by-pass feeder on the units to feed a proportional amount of boiler compound into the pump suction as the water was pumped to the coils. The boiler compounds consisted essentially of soda ash, tannins and alkaline phosphates compressed into balls or sticks.

The usual attempted rate of feed was 1 lb. of compound per 1,000 gal. for every 70–80 ppm. of hardness. This

was soon found to be quite inadequate for most waters. Part of the trouble arose from the erratic operation of the by-pass feeder and also from the inability to establish any real control. Even in territories in which the water supplies were considered "good" for steam locomotive operation, severe difficulties were encountered both from scale and corrosion. Although engine crews shut down the generators enroute once every 50 to 75 miles, to blow down the coils and separator, acid descaling was required as frequently as every ten days in order to keep the coil-inlet water pressures below 400–450 psi. In addition, the corrosion of the coils, particularly in the inlet end of the outer coil, was so severe that coil life was commonly less than one year. Figure 8 shows a sectioned set of coils restricted with acid-insoluble scale and severely corroded after nine months' service.

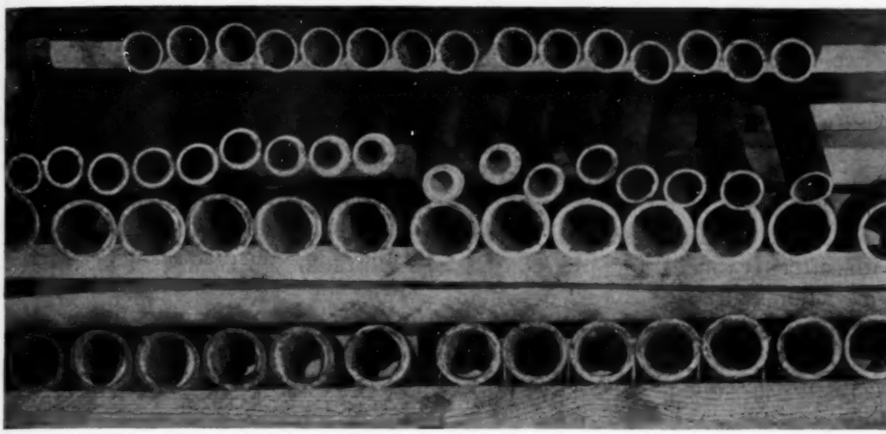

Fig. 8. Cross Section of Scaled and Corroded Coils

Next, small auxiliary pumps were tried as proportioners, by predissolving the water-treating compounds and adding the dissolved solution to small supply tanks installed on the locomotives as the source of supply for the auxiliary pumps. In the author's opinion, these have not been much more satisfactory than the by-pass feeders. Considerable difficulty has been experienced in maintaining the proportioners. Moreover, it is not feasible to change the rate of feed on the line-of-road in order to inject the proper amount of chemical into the waters of varying hardness which are supplied to the locomotive enroute. The size of the locomotive supply tanks usually requires refilling every 3–3½ hours of capacity operation of the steam generator. Very few runs are of shorter duration than 5 hours and several are as long as 54 hours. Thus, two to fifteen different waters may be used on a single run.

Train Steam Requirements

The amount of steam required for train heating in high-speed service during zero weather is frequently as high as 335 lb. per hour per coach. The steam requirements of coaches equipped with steam-jet air conditioning during hot weather probably is even 10 per cent greater. Since these requirements

must be met in order to make diesel-powered passenger train operation successful, a considerable capital expenditure is justified for facilities which will promote the satisfactory operation of steam generators.

Control of Scale Formation

Scale formation can be controlled by several methods of treatment. The type selected for use at a given station is dependent upon the original quality of the water available, the number of generators in service, the severity of the service and the capital expenditure justified to overcome the trouble.

Scale formation is being controlled by the use of distilled or demineralized water, by treating the water with zeolites or lime-soda and by internal treatment. Each of these methods can fill a definite need.

Distilled or demineralized waters, with after-treatment for pH control, are undoubtedly the most desirable types of supply, because they will result in scale-free operation and are the easiest to passivate chemically for corrosion control. Which type should be selected is dependent on the comparative cost. At terminals, sufficient steam trap discharges can often be readily collected to give adequate amounts of distilled water at relatively low cost.

Zeolite treatment, with after-treatment for pH control if necessary, is particularly adapted to water supplies that are initially clear and relatively low in total hardness and alkali salts. Under these circumstances, the results will be similar to those produced by distilled or demineralized water, and the zeolite method may be less costly.

Lime-soda treatment is adapted to waters high in bicarbonate hardness and low in alkali salts. Some sludge will be formed and will return to the supply tanks. The sludge will not produce scaling of the coils but it may lodge there and cause some control difficulties. Since there are a great number of lime-soda plants in service for the treatment of steam locomotive boiler water supplies, many of these facilities will continue to be used, particularly during the transition period in which both steam- and diesel-powered locomotives are employed.

There are several factors which limit the usefulness of internal treatment. To be successful, it must, of course, be properly proportioned; and, in addition, the chemical used must produce a relatively nonadherent sludge, to prevent the various water controls, heat exchangers and steam traps from becoming plugged with sludge.

Soda ash, tannin and phosphate mixtures are not believed adequate because of the character of the sludges formed. These sludges generally tend to settle quickly, adhere readily and pack to form deposits in the water tanks and controls which are difficult to remove by washing.

Calcined potassium carbonate is being utilized quite extensively with a good degree of success on low-hardness waters. Its use should probably be restricted to waters with a top limit of hardness of 250 ppm., since with higher-hardness waters the amount of sludge becomes excessive, requiring very frequent flushing of the water storage tanks on the locomotive in order to keep the water controls functioning properly.

Coil Corrosion Control

De-aeration is the only feasible method known which will completely stop the corrosion of the inlet coil.

Auxiliary equipment to give reasonably complete de-aeration is available for installation on the locomotive if the corrosion experienced is severe enough to justify it.

Tests made in an attempt to stop corrosion by feed-water pH control indicated that corrosion would take place up to a pH of 12.5. This is a pH value which cannot be justified economically. The higher the pH value of the feed water, however, the slower the rate of corrosion. Tests showed de-aerated water with a pH of 7.5 or above to be noncorrosive. After one year's service in a steam generator, during which the locomotive accumulated 240,000 miles, the inlet end of an outer coil was slightly corroded but was still suitable for at least one, and possibly two, more years of service. This record was accomplished by internal treatment which kept the pH value of the feed water at a minimum of approximately 9.8.

Attempts to fix the dissolved oxygen in the feed water chemically with sodium sulfite were unsuccessful because of the low temperature encountered. Unless the feed-water temperature is as high as 185°F., the speed of reaction is too slow to be of value in restraining the corrosion at the inlet end, and thus is of no use for this purpose.

Laboratory Control

No method of treatment can be successful without accurate and reliable control. This is very definitely a problem which can be solved only by a properly trained water chemist. He must, of necessity, exercise analytical control—both on the feed water and the steam separator return water—which is sufficiently frequent for him to know that the desired treatment is maintained at all times.

Summary

Since the water conditioning requirements of diesel locomotives are quite different from those of steam engines, very few of the existing steam locomotive water facilities are suitable for conversion to use with diesels.

In planning the installation of diesel locomotive water facilities, recognition should be given to the need for both cooling and steam generator water and to the different conditioning required for each usage. Basically, low-hardness, pH-adjusted waters of low total dissolved solids content are necessary for both. The waters satisfactorily conditioned for steam generators can generally be made adequate for the cooling systems by adding the proper amount of chromates and caustic soda. Thus, the same primary plant is used for both purposes, but different facilities for after-treatment are required.

Silica Removal With Iron Shavings

By Walter B. Leaf

A paper presented on May 6, 1948, at the Annual Conference, Atlantic City, N.J., by Walter B. Leaf, Research Technician, Denver & Rio Grande Western R.R., Denver, Colo.

ARTESIAN wells about 800 ft. deep at Alamosa, Colo., furnish the water supply used in road and switch engines and in the stationary power plant of the Denver and Rio Grande Western Railroad. In the past considerable trouble has been experienced with heavy scale in the power plant boilers, which are of the water-tube type and operate at 125-psi. pressure. Turbining of the tubes was necessary every spring and fall. The scale was so hard that many sets of cutters were worn out, and as much as eight hours' time was required to turbine a single tube. As many as 95 blistered and burned tubes had to be replaced each year.

Internal treatment was started about six years ago, using phosphate-tannin compounds, and magnesium hydroxide for silica absorption. Improved results were obtained, but it was still necessary to turbine the tubes.

Laboratory Investigation

A laboratory investigation of the problem was undertaken in 1944. The analysis of the water at that time is shown in Table 1. The temperature of the water leaving the ground is 74°F.

Several methods of silica removal were known. Absorption by aluminum or ferric hydroxide, and precipitation as magnesium silicate at high temperatures, were tried in the laboratory, but these methods required large chemical doses and increased the dissolved solids content of the water objectionably. The quality of the water is such that quite careful chemical control is necessary to keep it satisfactory for boiler use. Ion-exchange methods were considered but were discarded as being far too expensive for this high silica content.

It was found that freshly formed ferric oxide had a very high adsorptive capacity for silica. Figure 1, based on laboratory investigation, shows the amount of residual silica (in waters with an initial silica content of 70 and 120 ppm.) as a function of the quantity of iron rusted.

The curves demonstrate that the amount of silica removed per unit of iron rusted depends on the initial silica content and the amount previously removed. Thus, the rusting of 40 ppm. of iron reduces the silica content from 120 to 60 ppm., or one-half; an additional 80 ppm. of iron rusted is required to reduce the silica from 60 to 30 ppm.; and so on. Consequently the action is assumed to be one of adsorption.

A plant to treat 30 gpm. was constructed at Alamosa, consisting of a bin 5 ft. in diameter and 7 ft. high, full of steel lathe turnings; a sump; an ele-

vating pump; and a settling tank 7 ft. in diameter and 15 ft. high, with a sludge removal system in the bottom. Water was sprayed over the shredded metal, but very little rusting took place and consequently no silica removal resulted.

Pilot Plant Tests

Next a small pilot plant was built at Alamosa. A glass tube, 6 ft. high and 3 in. in diameter, was packed with lathe turnings and filled with water which flowed down through the shavings. A small stream of air was blown in at the bottom. Over several weeks' time this apparatus furnished rust at a good rate,

TABLE 1

Alamosa Water Analysis

Substance	Quantity *ppm.*
Calcium and magnesium carbonate	22
Sodium carbonate	18
Sodium bicarbonate	50
Silica	85
Sodium chloride and sulfate	17
Suspended matter	0
TOTAL DISSOLVED SOLIDS	192

with silica reduction to approximately 15 ppm. The water was fed in by bottle and small orifice, so that it could be pretreated with alum, acid and the like to increase the corrosion rate.

Based on operating data from this pilot plant, an 8×8-ft. wood-stave tank, with an air manifold in the bottom, was erected and filled with lathe turnings. When placed in service, it was a supreme failure, very little rust being formed after the first week. During the next year many schemes to accelerate corrosion were tried, but none with success. The wood-stave tank held about two hours of pumpage, and aeration in that time raised the pH of the water to 9.5, which was thought to give protection against corrosion. However, carbon dioxide gas, alum or sulfuric acid treatment reducing the pH to as low as 4.5 would not cause continued corrosion.

The steel shavings were heavily coated with rust, but this coating was very adherent and protected the steel against further corrosion. Although the coating could be broken off to a small degree by driving a bar into the mass, this method was not considered feasible for continued operation. Several additional air manifolds were driven into the tank, with solenoid valves and automatic control to admit

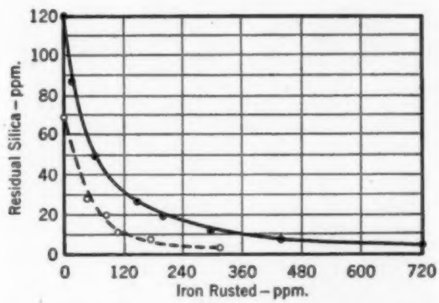

FIG. 1. Silica Removal by Ferric Oxide

large blasts of air at 90-psi. pressure every fifteen minutes. Some rust was thus broken off and washed away, but the results were not satisfactory.

The pilot plant had continued to produce rust for several weeks, as long as it was run, and the effluent was highly colored with finely divided hydrous ferric oxide. Silica reduction had been very satisfactory, and no reasonable explanation could be found for the failure of the full-scale plant. From time to time, various small pilot plants were set up in the Denver laboratory, which always produced rust in satisfactory quantity. After much investigation, it

was finally decided that the failure of the full-scale plant was caused by the type of water circulation involved. The circulation in the pilot plant was not rapid and consisted mainly of a simple downflow because of the slender shape of the vessel; in the 8 × 8-ft. tank, however, the circulation was general. In the pilot plant, by the time the water had flowed downward several feet, the silica was reduced to a low value and the remaining iron was not protected against corrosion. But in the large tank, high-silica water circulated all through the iron, so that a good protective film was rapidly built up, preventing further corrosion. In all probability, the pilot plant would have been rendered ineffective if it had been operated for a sufficient length of time.

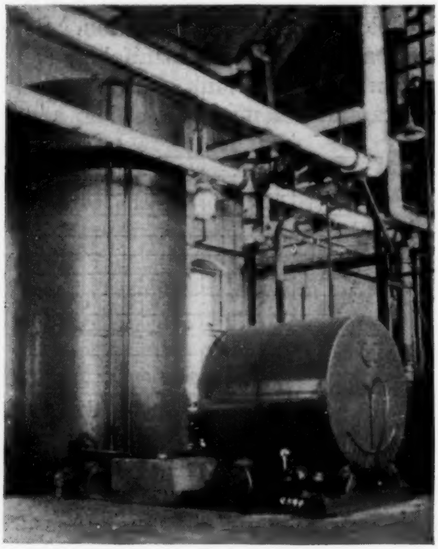

FIG. 2. Silica Removal Plant

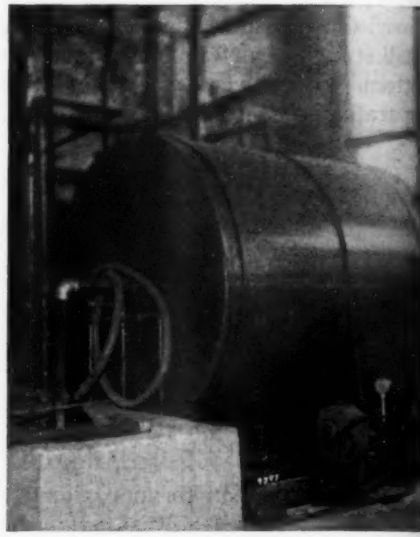

FIG. 3. Inlet and Outlet End of Drum

Cast-Iron Chips

The use of cast-iron chips from the railroad's wheel boring plants was then considered, and again the pilot plant technique was used. A small tube full of chips, with an air and water inlet at the bottom and an outlet at the top, produced rust in a most satisfactory manner. Therefore, 30 in. of the steel lathe turnings was dug out of the top of the wood-stave tank and about 8,000 lb. of cast-iron chips was poured in. Immediately the water became highly colored and the silica was reduced to 6 ppm.

Corrosion of a machined cast-iron surface is very rapid because of the electrolytic action between the iron and the free carbon particles, which are negative to iron. Thus, the tendency to rust is greater than the rate at which oxygen can be supplied to the iron by solution in water, unless the water circulation is extremely rapid. It was noticed that air bubbles rising through cast-iron chips in a glass tube followed a fixed path rather closely, and, consequently, not all of the iron

surfaces were touched by the bubbles. As a result, considerable black magnetic iron oxide (Fe_3O_4) was formed, which finally sealed up most of the spaces between the chips, and after several weeks the production of rust fell off.

The chips could easily be broken up by spading or raking, thereby loosening the old rust and allowing fresh rust to der with air and water inlet manifolds at the bottom and an axial outlet. Such a cylinder, 16 in. in diameter and 2 in. long, mounted on rollers with the axis horizontal, was made from sheet celluloid and about half filled with cast-iron borings. It was operated with Denver tap water for several weeks and later at Alamosa for a similar period at various rates. The results were gratifying

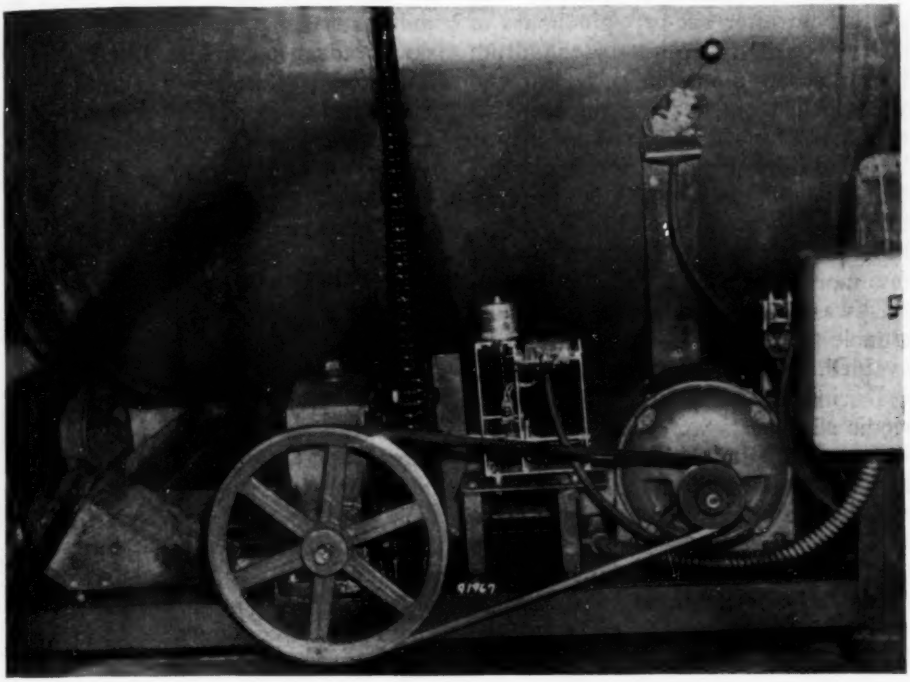

FIG. 4. Automatic Agitator

form. A motor-driven rake arm, installed in the top of the tank, functioned well for several months, but gradually the cemented boundary pinched in and made it impossible to operate the rakes. Thus, another scheme which had offered much promise at the start, failed.

Cast-iron chips can be more easily agitated than lathe turnings, so the next device to be tried was a tumbling cylinder

and a cylinder 4½ ft. in diameter and 4½ ft. long was built in the boiler shop from ¼-in. plate. It was mounted on inverted casters, and a drive chain, reduction gear and motor drive were provided (Fig. 2 and 3). Approximately 4,000 lb. of chips are required to charge it half full. The silica in the water was reduced to about 12 ppm., which was considered satisfactory. It was

thought that this amount would remain in solution in the boiler water.

Power plant workers were instructed to turn the drum upside down in both directions every four hours, and for six months or more its operation was quite successful. Then, gradually, rust production fell off. The chips were not cemented together but were heavily coated with an adherent rust film which was not easily broken off. It was found that after six or eight hours of nearly constant turning of the drum the rust coating finally loosened up and was washed out, leaving the chips in condition for further rapid rusting. This was encouraging, for it showed that the old chips could be reconditioned. Of course, the old ones might have been dug out of the drum every few months and fresh ones put in, but this was considered to be too much trouble and expense if it could be avoided.

During the work at Alamosa, periodic silica tests were run on the raw water, using the acid ammonium molybdate method and glass color standards. The silica content had always been 85 ppm. until the summer of 1946. On July 30 of that year the silica was found to be 170 ppm. and readings as high as 210 ppm. have been recorded. During the last year the silica has averaged approximately 120 ppm. The unusual feature is that the methyl orange alkalinity has remained constant at 90 ppm. regardless of silica variation. On July 31, 1946, the silica again tested 85 ppm. Thus, in 24 hours it broke down from 170 to 85 ppm., which is most unusual for an 800-ft deep well.

Tests on water from neighboring wells of various depths from 200 to 1,200 ft. show that the deeper water has a higher silica content. Because the shallower wells do not furnish much water, it will be necessary to continue using the present supply. Precipitation has been below normal in the San Luis Valley for several years, and it is hoped that the silica content will some day return to 85 ppm.

It is thought that the high silica content of San Luis Valley water is caused by the Great Sand Dunes, about 40 miles northeast of Alamosa. These dunes cover an area about 30 miles long and 10 miles wide, running part way up the slope of the Sangre de Cristo Range.

Automatic Agitator

In order to increase the amount of rust formed, an automatic agitator (Fig. 4) was installed in January 1948. With this device, the drum is rotated one half turn in each direction every fifteen minutes or a multiple of that period. A stoker timer controls the solenoid shown in the center of the photograph (Fig. 4), which tips a mercury tube in series with the holding coils of a magnetic reversing switch. This mercury tube drops into, or is pulled out of, a notch in a revolving disc driven by the reduction gear at about the same rate of revolution as the drum. Thus, when the solenoid is activated, the motor starts. The direction of revolution is controlled by one of the two mercury tubes on the tipping device shown near the top of the photograph. Two fingers, brazed on the drum, tip this double tube assembly one way or the other at the end of travel, and the motor is reversed. The rate of rotation of the drum is approximately one revolution in two minutes.

After about four minutes, the timer cuts off the solenoid, and the apparatus

continues to operate until the notch in the disc turns to the initial position, allowing the mercury tube to tip and stop the motor. Consequently, the drum is always brought to rest with the air manifold at the bottom.

It was found by trial that, with a silica content of 120 ppm., a 30-minute cycle was inadequate to keep the rust broken off so that rapid oxidation would take place. A fifteen-minute cycle produces sufficient rust to remove about 70 ppm. From the information in Fig. 1, silica removal is seen to be a function of the amount of rust formed, which, in turn, in the present apparatus, is a function of the amount of agitation of the cast-iron chips.

A new scheme to increase rust production has recently been instituted. Every Sunday morning the water to the drum is turned off, and a pint of muriatic acid is poured into the drum. This is sufficient to neutralize the alkalinity of the water present. Agitation continues every fifteen minutes; by Monday morning all the old coating has been broken off the chips, and rapid rusting then takes place. On Monday morning, the plant is placed in service, without flushing it out. No appreciable reduction in boiler water alkalinity is experienced. If the acid were not added, the aeration of the water over this long period would break down the sodium bicarbonate to carbonate and raise the pH to 9.5 or 10, thus reducing the rate of corrosion.

Other Features of Process

A number of points of interest which have been developed in the course of this research will be briefly discussed.

The hydrous ferric oxide formed in Alamosa water is largely colloidal and will not settle out of the water in the tank, where the upflow rate is about 4 ft. per hour. This colloidal condition is necessary for efficient silica adsorption.

Rust formed in distilled water is well coagulated and settles out rapidly, but if 90 ppm. of sodium bicarbonate is added, to simulate Alamosa water without the silica, the rust formed is finely divided and does not settle readily. Rust formed in Denver tap water containing, among other things, about 120 ppm. of calcium and magnesium bicarbonate is well coagulated, possibly being loaded down with calcium carbonate which results from the decomposition of the bicarbonate by aeration. The alkalinity and hardness of Denver tap water are materially reduced by aeration.

Rust formed in the absence of silica, if collected and added to silica-bearing water, has a variable adsorptive capacity, depending on its history. When only a few hours old, rust from synthetic Alamosa water (without the silica), or from Denver tap water, has approximately half as much adsorptive capacity as the same amount of rust formed in the presence of silica. Rust formed in distilled water has very little adsorption power when added to silica water. In both Denver water and distilled water the rust is coagulated, but the rust from Denver water has a higher adsorptive capacity than that from distilled water. Denver water rust several months old has very little silica removal capacity.

When rusting is rapid, as it is with fresh cast-iron chips, the color imparted to the water is a light orange. As the corrosion rate decreases, the color of the water and the coating on the chips darkens. Thus, success in silica re-

moval can be readily estimated by the color of the effluent from the drum.

Colloidal ferric oxide was found to be an excellent boiler compound. Early in the work with cast-iron chips, alum feed for coagulation was provided. The equipment was not very reliable, and the colored water entering the boiler was viewed with some misgivings. The boiler results were good, however. A thin slime coated the tubes and drums, under the water line. On drying out, this slime film was so soft it fell off the iron surfaces. Analysis showed it to contain 36 per cent silica and 26 per cent iron oxide. Thus, a scale of 36 per cent silica, which should have been extremely hard, was very soft. Based on this finding, a small drum, 2 ft. in diameter and 1 ft. long, was put into operation at the Grand Junction power plant merely to make boiler compound. Internal treatment with soda ash and tannin had failed to keep the boilers clean, but the addition of the iron oxide has cleaned off all the old scale, which was ⅛-in. or more in thickness. The Grand Junction water varies in hardness from 50 to 100 ppm., with approximately 10 ppm. of permanent hardness.

The presence of hydrous ferric oxide in the boiler water retards the rate at which sodium bicarbonate breaks down carbonate and hydroxide. Boiler alkalinities at Alamosa ran to about 70 ppm., with approximately one-third as hydroxide before the rusting process was started. With good silica removal and colored water, it is now found that about one-third of the total alkalinity remains as bicarbonate. No explanation can be offered at present for this peculiarity. Even boiling sodium bicarbonate solutions on a hot plate, with and without iron oxide, demonstrates the phenomenon.

With cast-iron chips, a silica content of over 35 ppm. builds up protective coatings which in time prevent further rusting unless severe agitation is used. Below 35 ppm. the rusting process proceeds with vigor. The dividing line of 35 ppm. applies to water similar to the Alamosa product and would vary somewhat with differences in the natural corrosive power of other waters. Thus, if the air used contains small concentrations of carbon dioxide, corrosion would probably proceed at higher silica concentrations.

There are a few variables in the process the effects of which are unknown. Possibly a careful control of pH at some value might increase the efficiency of absorption. This feature has not been investigated, since the constant aim has been to keep the plant as simple as possible, so that it could be operated with unskilled labor. Silica removal processes based on absorption with hydrous aluminum oxide floc seem to work best at a pH of approximately 8, so the present plant may be in the optimum range. A lower pH would accelerate corrosion but might possibly require after-treatment to condition the water for boiler use.

The use of this process for high-pressure boilers, where steam distillation of silica takes place, offers an interesting field for investigation. By introducing small quantities of iron oxide into the boiler, the evaporative tendency of the silica might be reduced, since the bond of adsorption seems very high. Boiling the iron-silica sludge in a caustic soda solution does not release the silica into solution, whereas dissolving the iron with hydrochloric acid does.

The exact form which the silica takes in solution is not known. The caustic alkalinity of the water is low, but the caustic alkalinity of all sodium silicate solutions investigated was high. The alkaline sodium content of the Alamosa water is assumed to be carbonate or bicarbonate.

The rusting process will remove the silica from a solution of sodium metasilicate. A solution of sodium metasilicate has a high caustic alkalinity, which can be destroyed by dissolving carbon dioxide in the solution. After standing for several weeks, however, the silica is precipitated out, thus showing instability. Consequently, the Alamosa silica has not initially dissolved as sodium silicate and then undergone carbonation at some point downstream, for the water is stable over long periods of time.

The removal of silica to obtain low residuals has been investigated at random. Denver tap water, with about 8 ppm., has been treated to zero content (as evidenced by lack of color in the ammonium molybdate test) after only 20 minutes' contact time. From the data presented in Fig. 1, it appears that a two- or three-stage process of rusting and coagulation would be most satisfactory in treating high silica waters to low values. The dotted line in Fig. 1 represents a mixture of Denver and Alamosa waters, which would probably be more corrosive than Alamosa water alone. The horizontal scale values are not guaranteed completely accurate, because of the difficulty in making an exact determination of this variable.

Approximately 40 cfm. of air is blown into the drum at Alamosa. The air manifold consists of ¼-in.-id. copper tubes spaced at 3-in. intervals, with holes 0.040 in. in diameter drilled every 1½ in. The holes are turned down, so that any water or sludge which may enter the tubes if the air is shut off will be blown out again. This is an important point in design and was discovered the hard way.

Corrosion of the inside of the drum has been very slight, most of the mill scale still being present, after eighteen months of operation. With the new weekly regeneration cycle in effect and lower silica concentrations expected in the future, the corrosion may be accelerated. Nevertheless, the drum is expected to last for ten years or more.

Bearings have had to be replaced in the inverted casters, which are loaded close to their rated capacity. The drive chain has been broken several times, although the theoretical load is only about one-fourth of its rating. This is thought to be due to the carelessness of the operators in turning the drum too far before reversing, because no trouble of the kind has been experienced under automatic control.

Tannin phosphate compound was reduced from 15 to 3 lb. per shift after cast iron was put in service. Boiler conditions were excellent except in the top row of tubes, nearly horizontal, where sluggish circulation allowed the upper half to carry steam and the lower half water. A ridge of very hard scale built up at this water line. Because other boilers of identical design, operating satisfactorily on internal treatment, have been found to give the same trouble, it seems that the design is somewhat at fault. The compound dosage was increased to 6 lb. per shift as a safety measure after this difficulty was encountered. It is intended, now that the rusting rate has been increased, to reduce the compound to a minimum consistent with good boiler conditions.

This has been the story of a hard four-year struggle to make iron rust. It took some time to find out that the high silica content gave excellent protection against corrosion. The research included problems in chemistry, electricity, mechanics and Rube Goldberg technique, since most of it was done in the war years, when desired devices were not obtainable and substitutes had to be developed. A plant has finally resulted, however, which satisfactorily handles water containing up to 200 ppm. of silica and is entirely automatic in operation, except for weekly regeneration and the daily opening of two dump valves. The operating expense is limited to the cost of repumping and of obtaining a small quantity of compressed air.

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *B.H.—Bulletin of Hygiene* (*British*); *C.A.—Chemical Abstracts; Corr.—Corrosion; I.M.—Institute of Metals* (*British*); *P.H.E.A.—Public Health Engineering Abstracts; S.W.J.—Sewage Works Journal; W.P.R.—Water Pollution Research* (*British*).

TREATMENT AND CONDITIONING—GENERAL

Recent Research and New Development in Water Treatment. J. G. Milton. J. Soc. Engrs. (Br.) p. 38 (Jan.–June '47). Recently developed methods of treatment of water, with particular reference to supplies for industrial purposes, dealt with and explained in simple language, no formulas given, but design and operating principles described and advantages of each one of methods noted concisely summed up. Methods reviewed include (a) lime-soda softening in which Spiractor app. prevents cementing together of sand grains and calcium carbonate crystals; (b) Precipitator and blanket-type softener for lime-soda softening without heating; raw water forced through zone of preformed sludge to hasten rate of pptn. and decreasing upward veloc. allows absolute gravitational pull on rising solid particles; (c) pressure hot-lime process in which water to be treated sprayed through steam space, thereby heated to within 3° of steam temp. and high percentage of D.O. removed; (d) base-exchange process in which sodium zeolite (compd. of oxides of aluminium, silicon and sodium) can remove calcium and magnesium from water and substitute sodium originally present in zeolite in place of hardness removed. Zeolite can be regenerated by soaking in soln. of common salt; (e) hydrogen-ion process, zeolite regenerated by salt or acid such as sulfuric or hydrochloric, can exchange hydrogen ions from sodium, calcium and magnesium ions in raw water, thus producing effluent contg. hydrochloric, sulfuric and carbonic acids corresponding to dissolved salts in raw water. Investigation to find absorbent of acids from hydrogen-ion effluent resulted in discovery that synthetic resins compounded would absorb weak acids; and (f) desalting of sea water by mixed silver-barium zeolite which when shaken with sea water causes dissolved salts to be pptd. Reduction of 90% salinity made. Paper illustrated by 12 figs., diagrams of apparatus being shown.—*Ed.*

Recent Developments in Water Treatment. E. L. Streatfield. Trans. Liverpool Eng. Soc. (Br.) **67**: 80 ('46). Coagulants commonly used are alum and sodium aluminate. Work carried out by Baylis in America on use of silicates as aid to coagulation shows promising results. Bentonite, another aid to coagulation, also developed in America. Coagulation by elec. process used for removing emulsified oil from condensate. Oil-contamd. condensate passes between electrodes, across which passes small direct current, during which time emulsified particles coagulated. Water then passes to rapid filter contg. sand, anthracite, or activated carbon. Small quant. of water contg. sol. solids has to be added to condensate to produce elec. conductivity. Conventional rectangular sedimentation tank with over- and under-baffles unsatisfactory. Walton and Key, as result of expts. at Alexandria, designed rectangular tank aimed at creating large horizontal eddies having no floc-supporting value. Circular settling tank also designed in which flocculated water enters tank through vertical port set so that water directed into tank at angle to tangent and set in rotation. Other investigations have not supported conclusions. Interesting development in filtration is use of anthracite as

filter medium. Little used in this country for water filtration. Return and admixt. of previously formed sludge with chemically dosed raw water for purpose of assisting softening or coagulation old and well-established principle. Recent development in stabilization of lime-softened water: use of carbonaceous zeolite as filter medium.—*H. E. Babbitt.*

Portable Water Purifier. DAVID H. QUINN. U.S. 2,434,958 (Jan. 27, '48). Purifier is primarily designed to supply drinking water from possibly polluted sources in camps, fields, etc.—*C.A.*

Purification of Humidifier Water. JAMES W. HAMMOND & J. D. LESSLIE. Textile Inds. **112**:1:68 ('48). Needs for methods of water purification used in humidifiers, and systems for protecting purity of water are presented.—*C.A.*

Electric Treatment of Water. E. LECLERC. Trav. Centre Études Eaux (Belg.) **111**:259 ('45); Chimie & Industrie (Fr.) **57**:358 ('47). Results are given [no details in French abstract] of tests on water treated electrically with very small alternating current. pH measurements showed very slight increase in alkalinity. It would seem that first effect of treatment is to change crystalline form of scale. Attempt made to explain phenomenon by theoretical considerations involving notion of electrical field created by charges on constituents.—*C.A.*

Trapping Sand in Water. LYNN PERRY. Eng. News-Rec. **140**:127 (Jan. 22, '47). Two parallel pretreatment units, consisting of upflow sand trap and propeller-agitated chemical mixing basin, included in expansion of Miami water filtration plant from 40 to 60 mgd. Sand trap will remove fine quartz sand picked up from pockets in limestone strata from which well water supply pumped. At upward veloc. of 0.0767 fps., anticipated that particles smaller than 80-mesh size will settle out. In recirculating mixing basin, veloc. of approx. 6.37 fps. will be maintained to prevent deposition of floc.—*Ed.*

Use of Phosphates in Water Treatment. M. REIGNIER. Tech. l'Eau (Belg.) **2**:9 (Feb. '48). Discussion of various types of phosphates, equivalent dosages required and properties of phosphates under various conditions, including precipitation and corrosion inhibition.—*Willem Rudolfs.*

Still and Pyrogen-Free Distilled Water. HARRY J. GOECKEL. Bul. Am. Soc. Hosp. Pharm. **4**:149 ('47). Factors, assemblies, precautions, and special problems encountered in prepn. of pyrogen-free water discussed.—*C.A.*

Chemical Removal of Scale From Water Lines. R. TUNNELL & J. T. BROWNING. Southern Power and Ind. **65**:11:50 ('47). Before cleaning pipelines, accurate samples of scale must be taken, with care to sample all layers, and inspection of line must be made by competent engr. Scale can be analyzed chemically, or by x-ray diffraction, and from this anal., solvent required can be detd. Typical applications of this method given.—*C.A.*

Removal of Ammonia From Water by Thermal Desorption. O. I. MARTYNOVA. J. Applied Chem. (U.S.S.R.) (In Russian) **19**: 1393 ('46). Concn. distr. coeff. K of NH_3 between aq. soln. and vapor phase at 100°—detd. by distn. of 20-ml. buffered samples of 50–70 mg./l. as function of pH—rises uniformly with rising pH from 0.915 at pH 6.0 to 12.25 at pH 8.6 and 13.3 at pH 9.0 and then remains const. Industrial desorption of NH_3 from water must therefore be done at pH not less than 9; with distn. column sufficient to insure equil., amt. of vapor expended about 8% of amt. of water. Process applied to river water contg. 28.14 mg./l. NH_3, 10.7 mg./l. PhOH, pH 7.8; with pH adjusted to 8.6 with NaOH, K was = 12.8. Vapor expenditure r related to initial and final concn. of NH_3, c_0 and c (in mg./l.) by $c = c_0\,[1 - (Kr/100)]$; with insufficient column, r greater or c higher. If stream of steam used instead of distn. column, one finds for amt. of steam required, v (in wt. %), for 100 kg., $\log c = \log c_0 - 0.057\ v$, if $K = 13$.—*C.A.*

Methods of Removing Fluorides From Water. F. J. MAIER. Am. J. Pub. Health **37**:12:1559 (Dec. '47). Evidence indicates that communal water supplies contg. over 1.5 ppm. of fluorides produce significant mottling of teeth, calcification defects and attrition of enamel. More than 1,000,000 persons in

over 500 communities in U.S. use water contg. excessive fluorides. Only one community now utilizing equip. specifically designed to reduce fluorides in water supply. Choice of method of fluoride removal depends on quant. and character of water and fluoride concn. Generally, in large plants where hardness reduction desirable, lime softening will remove fluorides in proportion to amt. of magnesium removed. Remaining fluorides reduced in contact filters or with alum-clay floc. Contact filters contg. tricalcium phosphates or resinous ion exchangers appear to have highest fluoride exchange capac.—*F. J. Maier.*

Removing Low Concentrations of Phenolic Compounds From Water. N. H. Brown Jr. & L. B. Miller. Pub. Wks. **79**:6:38 (June '48). Methods so far developed for elimination of low concns. of phenolic compounds from industrial wastes or raw waters intended for potable purposes are either costly or too difficult or dangerous. Present study to devise new chem. method involved four major points: (1) Adsorption of phenolic compounds by chemical flocculants. Slight adsorption of phenols was obtained using very high concns. of aluminum chloride, aluminum sulfate, ferric chloride, ferric sulfate or stannic chloride. High costs of flocculants make this method impracticable. (2) Reaction of phenol with metallic salts to produce insoluble or nonreacting compounds which can be adsorbed. In concd. solutions of phenol and iron salts complex ion salt is formed. In low phenol concns. encountered in water treatment, this formation evidently does not occur. (3) Reaction of phenols with organic reagents to form insoluble compounds, more readily adsorbed compounds, or compounds in which chlorination does not occur as readily as with free phenols. Various organic reagents would require concd. reactants, elevated temps. or pressures which are not applicable in water treatment field. (4) To find feasible substitute for chlorine in water disinfection that will not accentuate phenolic taste and odor. Bromine for water disinfection produces bromophenol which is more obnoxious in taste and odor than chlorophenol. Oxidation of phenols with chlorine dioxide possible. Because production of chlorine dioxide with chlorine gas and sodium chlorite difficult and dangerous, other methods studied. Sodium chlorate-hydrochloric acid method produced no reduction in phenols. Using sodium hypochlorite and sodium chlorite at pH of 8.8, partial destruction of phenols observed at concn. of 0.6 ppm. (calcd.) chlorine dioxide. Complete destruction of 0.1 ppm. phenols with 10 ppm. (calcd.) chlorine dioxide. This method effective, efficient and eliminates hazards of handling chlorine gas.—*F. J. Maier.*

Removal of Silica and Other Impurities From Water by Precipitation. Paul C. Goetz & Howard L. Tiger. U.S. 2,428,418 (Oct. 7, '47). Apparatus and procedure is described for removing SiO_2 and fluoride. Six examples are given, one being cited here to indicate steps involved: Raw H_2O containing 2.5 mE/l. of total hardness, of which 0.3 mE/l. was ionic Mg and 16–18 ppm. was SiO_2, was treated with CO_2 gas. Purpose was to dissolve CO_2 in H_2O. Ionic Mg content was increased to 3.0 mE/l. by agitation with Mg sludge drawn from precipitating tank. This H_2O was introduced continuously into precipitating tank and dosed with slight excess of dolomitic lime containing 32% MgO, to effect softening. This was agitated at 19° with 5.3% by weight of Mg-rich sludge for about 40 min. Effluent was found to contain 2.3–3 ppm. SiO_2. Process is described as effective and economical in enriching H_2O in ionic Mg which can be subsequently precipitated to remove fluoride and SiO_2. In fluoride removal, flue gas recommended, since large quantities of ionic Mg must be precipitated. Apparatus in use for softening processes may be readily converted, or method may be employed in conjunction with hot or cold lime-soda softening process. Two figures illustrate construction of equipment. Equations supplement chemical reactions involved.—*C.A.*

Silica in Water and Methods of Treatment for Its Removal. M. Verbestel. Trav. Centre Études Eaux (Belg.) **111**:207 ('45); Chimie & Industrie (Fr.) **57**:41 ('47). Processes for removal of SiO_2 from water are not numerous and never 100% effective. I. G. Farbenind. process and Reignier laboratory processes have been found satisfactory.—*C.A.*

The Use of Sodium Hexametaphosphate for the Treatment of the Circulating Water in the Condensers of the Thermal Central Stations of the Ruhr District. M. Chalmot. Rev. Ind. Minerale. (Fr.) **524**:515 ('47). Addn. of

sodium hexametaphosphate has proved to be very beneficial in preventing scale and pptn. of carbonates in pipes and tanks. $CaCO_3$ pptd. by decompn. of bicarbonate in water when partial pressure of CO_2 drops below equil. value as given by corresponding temp. and when satn. point exceeded or changed, according to $Ca(HCO_3)^2 \rightleftarrows CaCO_3 + CO_2 + H_2O$. Very small quants. of $(NaPO_3)_6$ suffice to prevent liberation of CO_2 and to increase soly. of carbonate and elevate satn. point. $(NaPO_3)_6$ combines with Ca ions in salts which constitute hardness of noncarbonated water and is pptd. finally in form of slimy Ca metaphosphate, when amt. of hexametaphosphate exceeds 2 mg./l. Few installations described.—*C.A.*

Incrustations in Condensers and the Treatment of Water With Hexametaphosphate. M. VERBESTEL. Trav. Centre Études Eaux (Belg.) **111**:245 ('45); Chimie & Industrie (Fr.) **57**:358 ('47). In condenser, temperature of water rises, which involves: (1) decrease in solubility coefficient of CO_2; (2) decrease in partial pressure of CO_2; (3) increase in H-ion concentration by modification of ionization constant of water. There follows supersaturation with respect to CO_2. In cooling tower, excess CO_2 is liberated and Ca^{++} concentration increases with formation of layer of $CaCO_3$. Addition of metaphosphate inhibits precipitation of $CaCO_3$; it gives with the latter relatively larger crystals than those formed in absence of the reagent (up to 10^6 times larger). Their shape and size do not lend themselves to compact felting. This favorable effect has been observed in Cu containers. The hexaphosphate content in circulating water must be maintained at about 2 mg./l. Concentration of stock solution should not exceed 0.1%.—*C.A.*

Sedimentation Basin Design. C. KELSEY MATHEWS. J. Missouri Water & Sew. Conf. **15**: 4: 49 ('44). Sedimentation basin discussed in relation to other functions of modern water treatment plant. Dispersion of chem., condition or floc formation, settling and filtration mentioned as principal functions. Sometimes fifth and sixth functions incorporated: namely, plain sedimentation for waters having heavy turbidity as in Missouri R. water and finishing basin in softening plant. Latter provides for sedimentation of residual $CaCO_3$. Principles of design of sedimentation basin discussed with reference to its fundamental performance to obtain best results economically. Design presented to decrease turbulence and short-circuiting. Adaptation of principle of radial flow in large plant in Kansas City, Kan., given in detail. Cross-flow basins and effluent devices used on large cross-flow basins described with reference to advantages and operation. Retention period depends on type of H_2O and type of treatment. Improvements made it possible to increase capac. of basins at Kansas City, Kan., from 1922 design capac. of 100 mgd. to 150 mgd. without enlarging basins, in addn. to obtaining better removal of turbidity. Attention called to details in design of modern sedimentation basis such as: covered basins in cold climates, adaptation to topography, correlation with existing plant structures and adaptation to various types of sludge removal equip.—*C.A.*

BOILERS AND FEED WATER

Fundamentals of Feed-Water Treatment. E. W. FELLER. Power **91**:12:63 ('47). Subjects discussed: scale formation, corrosion foaming, caustic embrittlement, clarification, softening (cold, hot and ion-exchange), silica removal, internal treatment, de-aeration and evapn., and blowdown. Survey of chemistry of water, its impurities, their actions, and chemistry of their control given. Suggestions as to testing, anal., and interpretation of results obtained given.—*C.A.*

Notes on Changing Feed-Water Treatment in Boilers. CHARLES W. PARKS. Power Plant Eng. **53**:12:96 ('47). Changing from internal to external treatment brings about certain different reactions, most interesting of which involve alkalinities and concentration.—*C.A.*

Corrosion in Boiler Feed-Water Treating Systems. III. LEO F. COLLINS. Power Plant Eng. **53**:12:114 ('47). Corrosion of pipes, tanks, materials and metals in systems using zeolites and acids, and for degasification, is discussed. Recommendations as to metal or treatment, such as lining or coating, are summarized. In acid system, concentrated H_2SO_4 and 75% H_3PO_4 are studied, both as received and diluted for use.—*C.A.*

Boiler Feed-Pump Corrosion? Here's What You Can Do About It. H. L. Ross. Power Generation **52**:2:104 ('48). Lower pH values and lower total solids resulting from refinements in feed-water treatment have created unexpected problems of corrosion-erosion. Raising pH and recirculating concentrated boiler water to raise total solids are suggested. Possibilities of successful protective coatings and use of new materials in new pumps are also touched upon.—*C.A.*

Materials in Boiler Feed-Pump Construction. H. L. Ross. Combustion **18**:10:43 (Apr. '47). Author reviews influence of various factors on corrosion-erosion when employing carbon steel; among these are low pH of the feed water and addition of sodium sulfite. Use of corrective materials for pump parts discussed.—*Corr.*

Electronic Treatment of Boiler Water. M. Déribéré. Énergie (Fr.) **31**:242 ('47). Experiments reported made with "electric buoy," pear-shaped glass bulb of about 10-cm. diam. filled with rare gas under low pressure and large drop of Hg. 50–100 l. of water per hr. were treated by immersion. It was found that no scale was formed later in boiler but rather an easily removable slime was deposited and boiler walls were kept clean. Old scale deposits softened after some time and could also be removed by water jet instead of by mechanical force.—*C.A.*

Water Conditioning for High-Pressure Boilers. A. C. Dresher. Natl. Engr. **52**:24 ('48). Four important requirements for satisfactory boiler feed water are: zero hardness and elimination of sludge and scale, low total solids, low concentration of silica, low and controllable alkalinities. Means of obtaining these conditions discussed.—*C.A.*

Facts and Factors of Boiler Corrosion. K. R. Hodges. Mass Production **52**:88 (May '47). Effects of overheating as well as chem., electrochem. and galvanic action which cause common corrosion difficulties discussed. Includes table of min. air-heater metal temps. for stoker, pulverized-coal and oil firing, and emphasizes necessity for avoiding dew points of flue gases.—*Corr.*

Corrosion and Embrittlement of Boiler Metal at 1350-lb. Operating Pressure. L. E. Hankinson & M. D. Baker. Trans. A.S.M.E. **69**:479 (July '47). After 7 years of operation, three 1350-psi. boilers at Springdale Station (West Penn Power Co.) developed type of barnacle corrosion and metal embrittlement which caused considerable apprehension regarding safety and continuous operating ability of these boilers. Corrective steps included reduction of D.O. content of feed water to 0.02 ppm. or below, maintenance of sulfite at 3–10 ppm. in boiler water and reduction of ammonia content of feed water which lowered amount of copper and its compounds in boiler sludge. As result, barnacle development and metal embrittlement stopped. Concluded that barnacle growth and embrittlement stopped when sulfite feeding resumed. Reduction of oxygen in feed water helpful.—*Corr.*

Experience With Internal-Boiler-Surface Corrosion in 1450-lb. Open-Pass Boilers at West End Station of the Cincinnati Gas and Electric Company. E. H. Mitsch & B. J. Yeager. Trans. A.S.M.E. **69**:487 (July '47). Pit type of corrosion occurred in Apr. '40 after 3 years of operation without difficulty. In Feb. '41 first failure by corrosion at rolled joints of tubes occurred. This type of corrosion stopped being active about beginning of '42 and had not recurred up to June '46. Conditions of operation, boiler water concentrations, and other factors described and compared in order to determine causes of corrosion or to determine factors responsible for arresting it.—*Corr.*

Evaporator Recovers Blowdown. S. H. Dowdell. Southern Power and Ind. **65**:11:58 ('47). Although make-up feed water required for boilers operating at 900°F. only 2%, necessity of keeping silica content low to avoid deposits on turbine blading made it necessary to use blowdown of about 0.5% for extended periods. This constituted sizable loss of both heat and water. Major part of these losses elimd. by running continuous blowdown to evaporator shell, after throttling water through flash chamber to avoid possible danger to evaporator tubes, or possible carry-over. Net saving of more than $1000 per yr. realized at this 30,000-kw. steam-elec. plant.—*C.A.*

Evaporator-Purifier for Boiler Feed Water. Edward A. Bertram. U.S. 2,428,768 (Oct. 14, '47). In described apparatus, condensate obtained from water vapor by indirect heat

exchange with raw feed water is used further as scrubbing medium for such vapors. Means are provided for periodic or continuous discharge of concentrated solids. By this method high degree of solid separation is obtained and apparatus may be used successfully for purification of sea water.—*C.A.*

Investigation Into Corrosion Problems at the Fulham Power Station. Metropolitan Borough of Fulham, Elec. Dept. Brochure, 50 pp. (Nov. '46). Following explosion in boiler unit at Fulham Power Station which disclosed large-scale corrosion, investigation carried out which is here reported. Concluded that prime cause of trouble was incorrect water treatment during early life of plant. Methods and equipment have been revised to avoid corrosion troubles and to provide facilities for rapidly checking and controlling bad conditions as they arise.—*Corr.*

Causes of Corrosion in High-Pressure Boiler Tubes. Paul M. Brister & J. B. Romer. Petroleum Engr. **18**:8:60 (May '47). For high-temp. superheater tubes, paper shows how temp. shock affects rate of corrosion on steam side and gas side of tube. With proper selection of ferritic type chromium-molybdenum steel alloys, steam and flue gas corrosion not troublesome for metal temps. up to about 1200°F. Stainless steels satisfactory for structures somewhat above 1200°F. For structural members, such as hangers and supports, chromium-nickel steel alloys preferred for elevated-temp. service. Type of corrosion that has been quite serious, although not prevalent, in carbon-steel tubes in high-pressure boilers appears in form of intergranular disintegration of metal adjacent to pit that is filled with iron oxide. Usually deposits of metallic copper and oxides of copper present in zone affected by corrosion, but authors point out that metallic copper often found in boilers not troubled by corrosion. Dissolved ammonia in boiler feed water can bring copper into boiler, from contacting materials contg. copper. Hence, ammonia in feed water should be reduced as much as possible; boiler water should be maintd. at satisfactory pH; D.O. should be reduced to as nearly zero as possible and excess of sulfite maintd. in boiler water. Oxygen and copper believed to be causes of this trouble. Severe corrosion in superheaters appears to come about as follows: (1) thin, tightly adherent oxide deposit forms on both steam side and gas side of tube wall; (2) temp. shock of relatively low-temp. steam or steam and water from deslaggers causes cracking of oxide due to different thermal expansion characteristics of oxide and metal; (3) surface exposed at base of cracks becomes oxidized; (4) this cycle repeated many times; (5) layer of oxide on inside metal surface raises metal temp. in tube, thus increasing oxidation rate; (6) progressive oxidation from both inside and outside of tube wall reduces thickness of wall and increases stress; (7) increased temp. reduces strength of metal, which, together with increased stress, causes accelerated creep of metal; (8) accelerated creep continues until failure occurs. Authors concluded that chromium-molybdenum steel alloys containing 2–9% chromium and 0.5–1.0% molybdenum, when properly selected for expected temps., are very satisfactory for use with metal temps. up to 1200°F. Above this temp., stabilized 18–8 stainless steel alloy appears satisfactory.—*Corr.*

Some Experiments on Corrosion of Steel by Boiling Water. A. J. Gould & U. R. Evans. J. Iron Steel Inst. (Br.) **155**:195 (Feb. '47). Behavior of steel in boiling water shown to be detd. largely by position of solid corrosion products formed. Under anaerobic conditions steel reacts at first with water, elimg. hydrogen, but film is formed over surface, so that attack over long periods very slight. In presence of oxygen, conversion of ferrous hydroxide to magnetite, or rust, appears to take place to some extent at distance from metal, so that film discontinuous, and serious corrosion occurs. Salts tend to increase and sodium hydroxide to diminish, attack under aerobic conditions. Copper deposited on part of steel increases intensity of attack in short expts. but not in long ones.—*Corr.*

A Note on the Selective Corrosion of Phosphor Bronze in Hot Water Service—Paper 1048. W. D. Clark. J. Inst. Metals (Br.) **73**:5:263 (Jan. '47). Phosphor-bronze pump impellers handling hot feed water and condensate on power station appeared to corrode similarly to dezincification. Microscopic, chem. and x-ray anal. showed phenomenon to be due to penetration of zeolite-softened feed water into porous sections of casting and resultant formation of particles of copper and stannic oxide. Attack at machined surfaces much greater than that at "as-cast" surfaces

On "as-cast" surface, attack had progressed in complex manner, leaving number of lamellar residues.—*Corr.*

External Deposits on Boiler Heating Surfaces. ANON. Combustion **18**:26 (May '47). Digest of report issued by British Boiler Availability Com. covering investigation of form and compn. of deposits in large number of boilers examd. Mechanism of deposit formation investigated and discussed; and behavior of sulfates, bisulfates, phosphates and chlorides studied, particularly chem. changes taking place in vapor phase.—*Corr.*

Investigation of Acid Attack on Boilers and the Effect of Repeated Acid Cleaning on the Metal. H. C. FARMER. Trans. A.S.M.E. **69**:405 (May '47). To minimize corrosion in acid-cleaning of boilers with hydrochloric acid inhibited with Dowell A-12, following recommendations made after extensive lab. tests: (1) cleaning soln. temps. should not exceed 140°F.; (2) acid concn. of 5% desirable, using 2-stage operations, rather than stronger solns. if deposit heavy; and (3) contact time should not exceed 6 hr. Also found that unstressed or stress-relieved metal shows lower metal loss than stressed metal. Observance of these precautions enables operator to acid-clean boilers with assurance of reduced corrosion or metal attack. Test procedures, chem. reactions involved and their results discussed.—*Corr.*

Compound Inhibits Corrosion Due to Dissolved Carbon Dioxide. Heat., Piping & Air Cond. **19**:4:164 (Apr. '47). Morpholine, volatile compound for inhibiting corrosion due to CO_2 in steam and condensate return lines of heating or processing systems, developed by Carbide and Carbon Chemicals Corp. It is an alkali which is designed to control acidity due to free CO_2 in feed water, or CO_2 resulting from decomposition of soluble carbonates. It evaporates with water in definite proportions so that any desired alkaline value in steam generated can be maintained by adjusting concentration in boiler. Recommended for feed-water treatment where extensive piping or condensing surfaces are present in low or medium pressure systems.—*Corr.*

Determination of the Degree of Salinity of Boiler Water. C. B. NIELSEN. Ingeniøren (Denmark) **55**:30:M55 ('46); Chimie & Industrie (Fr.) **57**:359 ('47). Degree of salinity is usually determined by drawing off about 1 l. of boiler water directly into cylinder or beaker and determining salinity by means of a hydrometer. As long as steam pressure is low, results are satisfactory; but in usual marine drum-boilers where pressure reaches 13–17 kg./sq.cm., there is violent evaporation when water sample is drawn off; this results in concentration of solution, necessitating application of correction, the principle of which is illustrated graphically [not in French abstract] and which can be plotted as function of pressure inside boiler.—*C.A.*

Material for Removing Dissolved Silica From Boiler Feed Water. THOMAS L. PANKEY & CARROLL E. IMHOFF. U.S. 2,430,300 (Nov. 4, '47). Activated silica-adsorbing material prepd. by mixing 1.5 to 4.5 parts $Mg(OH)_2$ and 1 part sol. silicate (expressed as SiO_2) with at least 1 part of water per part of mixt., to form light slurry which is heated at approx. 212°F. for 1–3 hr. Reaction mixt. should be adjusted to total alky. of less than 100 ppm. Dissolved silica content of water used must be considered in detg. amt. of sol. silicate to add. X-ray tests indicate no new compd. formation.—*C.A.*

Electrical De-aeration Licks Corrosion in This Plant. V. RODWELL. Power **91**:5:92 (May '47). Laboratory tests showed such promising results that power plant de-aerators at Slough Estates, Ltd., England, were revamped and electrodes installed so boiler feed water could be treated electrically. Basic treatment, corrective measures, test results, plant application, process operation and operating results discussed.—*Corr.*

Feed-Water De-aeration. Why and How. R. S. WISE & R. T. HANLON. Natl. Engr. **51**:876 ('47). Most common sources of high dissolved O in feed water and theory of mechanical de-aeration discussed.—*C.A.*

Oxygen in Boiler Feed Water. WILLIAM B. GURNEY & L. YOUNG. La. State Univ. Eng. Experiment Sta. News **3**:6 (May '47). Residual D.O. in presence of excess sodium sulfite concns. (greater than that of D.O.) is determined by two procedures: In Procedure 1, liberated iodine reacts with any sulfite before sample titrated; in Procedure 2, sulfite is

oxidized to sulfate prior to regular procedure, by introducing known amount of iodine. Procedure 1: To 500-ml. and 250-ml. feed-water samples respectively, add, with mixing, 2 ml. of manganous chloride, 2 ml. of alk. potassium iodide and 2 ml. of sulfuric acid. To 500-ml. bottle add 0.2 ml. of potassium bi-iodate and titrate with thiosulfate (B). Oxygen or sulfite is indicated according to whether $B - 0.2$ is positive or negative. Add 250 ml. of distilled water to 250-ml. bottle and titrate with thiosulfate (C). Oxygen or sulfite is indicated according to whether $C - 0.2$ is positive or negative. If oxygen is present, its amount equals $B - C$; if sulfite is present, its concn. is 7.4 $(B - C)$. Procedure 2: To 500-ml. and 250-ml. feed-water sample add, with mixing, 0.2 ml. of $N/32$ iodine, 2 ml. of manganous chloride, 2 ml. of alk. potassium iodide and 2 ml. of sulfuric acid. Titrate 500-ml. bottle with thiosulfate (D). Oxygen or sulfite is indicated according to $D - 0.2$ being positive or negative. Add 250 ml. of distilled water to 250-ml. sample and titrate (E). Oxygen or sulfite is present according to $E - 0.2$ being positive or negative. Oxygen equals $D - E$; sulfite equals $7.4(D - E)$. In absence of sulfite, $B - C$ equals $D - E$. When oxygen is present with sulfite, net iodine in $B - C$ should be less than $D - E$, difference being equivalent to amount of oxygen. Feeding of sulfite equivalent to 0.03-ppm. negative oxygen markedly reduced corrosion in boiler drums at water line. Remaining corrosion was eliminated by adding sulfite to phosphate used for direct feed to drums.—*A. A. Hirsch.*

An Evaluation of Test Methods for the Determination of Dissolved Oxygen in Deaerated Boiler Feed Water. J. F. SEBALD. A.S.T.M. Preprint No. 118, 17 pp. ('47). Four test methods generally accepted as reliable are considered for evaluation as to performance: Winkler; Schwartz-Gurney "A"; Schwartz-Gurney "B"; and U.S. Navy Laboratory modification of Schwartz-Gurney "A." Area of investigation; selection of analytical equipment, test site and mechanical equipment; test program and its results described.—*Corr.*

Algae, Scale and Corrosion Control. G. F. LEBRECHT. Ice Refrig. **112**:1:35. Series of tests for control of corrosion in ammonia condensers performed using following chemicals as inhibitors: lime, caustic soda, sodium silicate, sodium silicate combined with soda ash, caustic soda and phosphate, and phosphate alone. Specimens were pieces of mild steel about ½" square and ¼" thick, highly polished on 2 opposite sides. Impossible to control pH values to extent that any corrosion protection could be obtained without forming excessive scale. Best treatment obtained using form of sodium metaphosphate which shows avg. weight loss of 4 mg. per 500 sq.cm. Results tabulated.—*Corr.*

Improvements in an Alum Flocculation Process, Following Difficulties With a Domestic Supply Used as Feed Water for a High-Pressure Boiler Plant. J. P. BEVERIDGE, G. COOKE, N. STRAFFORD & P. F. WYATT. J. Soc. Chem. Ind. (Br.) **66**:267 ('47). Difficulties in operation of high-pressure boiler plant were traced to residual Al_2O_3 in domestic water supply. Satisfactory water containing less than 0.1 ppm. Al and having color of less than 5 Hazen units was produced by adjusting pH before coagulation to 5.8–6.4, by automatically controlled addition of soda ash. Automatic pH adjustment also was found to decrease amount of coagulant used, as compared to normal alum flocculation processes.—*C.A.*

Hydrogen Zeolite-Treated Water Dissolves Boiler, Superheater Scale. THOMAS L. B WEBB & JOSEPH D. YODER. Power **92**:1:9 ('48). Uninhibited 0.01–0.03% acid, such as might be prepared by passing normal water through hydrogen zeolite softeners has been used successfully to remove superheater scale. It has also been used in boilers and for external cleaning. Suggested procedure outlined.—*C.A.*

Mixing the Effluent of a Potassium Base Exchanger With Water for Use in Boilers. GEORGE W. SMITH. U.S. 2,433,167 (Dec. 23, '47). Process described wherein relatively inexpensive salt, such as Na_2CO_3, $NaHCO_3$, Na_2SO_4, $NaNO_3$, or Na phosphate—ortho, meta or para—is converted into corresponding K salt by passing through K base exchanger. Regeneration is effected by low-cost K salt such as KCl. K salts obtained are useful in treatment of water for steam boilers. M salts may be substituted for Na salts in process. Flow diagram included.—*C.A.*

Gage-Glass Condensate Cracks Metal by Pocketing at Drum Counterbore. J. A. KEETH. Power **91**:8:78 ('47). Corrosion fatigue due to stress and presence of corrosive agent cause of serious cracking of boiler drums at lower water column connection and feed line entrance. Stresses due to temp. differences, and corrosive agent is pure water or condensate which has low pH value.—*C.A.*

ALGAE CONTROL

Fresh Water Biology and Water Supply in Britain. W. H. PEARSALL, A. C. GARDINER & F. GREENSHIELDS. Fresh Water Biol. Assn. of the British Empire. Sci. Publication No. 11. 90 pp. ('46). This pamphlet designed to give general acct. of fresh water biology as it bears on water works practice. Water undertakings, other than those dealing with perennial wells, require some form of storage in order to provide adequate supply of water to consumers throughout year. Storage in reservoirs may give rise to heavy growths of fresh water life which may cause deterioration in filtration eff. and may give rise to taste and odor troubles in water through decompn. of algae and diatoms. It has been for many years concern of those in charge of lake and reservoir supplies to study flora and fauna with view to their reduction and control. Acct. given here is result of many years of intimate observations and practical experience of lakes in northwest England and of reservoirs of Metropolitan Water Board fed from Thames and Lea R. Authors have made sound and practical contribution to fresh water biology as it applies to these sources of water and have given, in simple language, explanations of biol. problems. Large rooted plants do not thrive to such depth in water as do algae, but design of new reservoirs should be such that only relatively small area will support rooted plant growth because they produce accumulation of nutrient material in bottom mud. Phenomenon of stratification described in simple terms, and its influence on provision of nutrients for fresh water life easy to follow. As light and temp. increase in spring, there is outburst of plant growth with max. in May. Growth of plankton animals follows and is augumented in late summer by larger carnivorous types. In summer too there is usually some growth of algae, probably of blue-green variety, presence of which indicates poln. of water by org. matter. Not uncommon to find growth of blue-green algae after autumnal leaf fall. It has become increasingly evident that amt. of nutrient material available affects both rate and amt. of algal growth. Thus, given vol. of Lake Windemere water would contain only 1/20 of no. of cells of *Asterionella* as would reservoir supplied from Thames R. which has much higher content of nutrient salts. Throughout publication, authors have stressed important part played by bacteria in biology of water. Both aerobic and anaerobic decompn. takes place in bottom mud. It has been observed that if aerobic conditions maintd. in lower layers of water, less likelihood of release into water of nutrient substances produced by anaerobic action in deeper layers of mud. This is another point which should be considered when designing new reservoirs. Biol. control of water supplies involves attention to catchment area and water before it enters lake or reservoir; observation of stored water and of its developing biol. character; treatment of this water during filtration and distr. Methods of plankton collection and estn. described in detail both in text and appendix, and form most valuable portion of booklet, bringing together work of many observers. Water works biologist not so concerned with those algae scantily represented in plankton. In general, algae do not cause trouble until present in fairly large numbers, although small representations may give guide to changing conditions, and some algae impart strong taste and odor to water even in low concns. "Drop" method of counting devised in Laboratories of Metropolitan Water Board, gives fairly accurate counts in min. of time, and, although counts of less than 25/ml. cannot be obtained, such low concns. do not usually give trouble on filters. One section has been devoted to forecasting and, like all forms of prognostication, liable to fail at times. More data available and longer experience of observers means more accuracy in forecast of algal growths and declines. Regular forecasts of biol. behavior of reservoirs extremely valuable, and points to be watched for are described in text and will be very useful to others in charge of reservoirs. In section

dealing with biology of slow sand filtration, emphasized that we are dealing not only with algae from feed water, but also with considerable pop. which may be sessile or subsessile diatoms and filamentous chlorophyceae. Again, purif. in slow sand filter not only that of micro-strainer, but there are also vital biol. actions of photosynthesis, ingestion of particles, and breakdown of org. matter. Small animals such as helminths, rotifers, insect larvae and protozoa ingest larger particles on surface of sand, and final degradation to simple inorg. salts takes place by bact. action in depths of sand, bacteria functioning as gelatinous film on sand grains. Tastes often believed to originate in reservoirs, but considerable number of taste troubles arise on filter beds themselves. Blue-green algae may decompose in filters, giving rise to aromatic tastes; musty taste may arise in cold weather when surface of water covered with ice, anaerobic breakdown continues but, owing to lack of oxygen and low temp., activities of nitrogen-oxidizing bacteria are in abeyance. Copper sulfate one of best algicides. It should be applied before algae reach numbers that will give rise to difficulties. This "prophylactic" method insures that, instead of masses of dead cells carrying nutrients to bottom of reservoir, which are available to give trouble later, pioneer cells killed off and nutrient salts of water remain in soln. Problems discussed give good idea of difficulties encountered in dealing with water supplies. Many biol. problems of economic importance for soln. of which there is as yet insufficient information. One can do no better than quote the authors' final words. . . . "The pamphlet will have served its purpose if it makes possible the collection of a still more varied and wider range of data."—*B.H.*

The Control of Aquatic Plants. John D. Fleming. J. Missouri Water Sewerage Conf. **17**:4:14 ('46). Problems caused by aquatic plants in water works briefly discussed. Algae, slime organisms and aquatic weeds described, especially in relation to difficulties that arise for water works engr. Problems created are sanitary and eng. Production of tastes and odors by algae and slime formers frequently renders H_2O unpalatable to consumer. Upsetting of stream's biol. balance by prolific growth of algae frequently affects O_2 supply and this affects fish life. When O_2 drops below 2–3 ppm., lake can be converted to graveyard for aquatic life. Certain blue-green algae give off toxic substances that are capable of killing lab. animals, and cattle have died from drinking H_2O infected with such algae. Growths of such organisms clog sand filters in very short periods of time. Offensive odors developed from heavily infected lakes and pools render them undesirable for bathing and boating and also frequently cause accidents. Industrial processes requiring H_2O frequently adversely affected by algae. In heat-transfer and air-conditioning equipment algal growths and slime formers attach to surface and have high insulating effect. Control methods discussed in detail. Use of $CuSO_4$, Cl_2, chloramines and combination treatments described. Mention also made of mech., phys. and chem. methods for continuous control. Use of Na pentachlorphenate applied to number of problems and especially in relation to weed control. Pointed out that 0.2 ppm. quite toxic to fish. Thorough understanding of causative factors involved in given problem necessary, and great deal of research has been conducted in recent years. —*C.A.*

New Ideas in Applying Copper Sulfate to Reservoirs. Wtr. Wks. News, N.Y. State Dept. of Health; Pub. Wks. **77**:18 (Aug. '46). Series of discussions by Elon P. Stewart, Joseph Griebel and John Kingsley, describing methods used to control algae growths in open reservoirs. Soln. of copper sulfate sprayed on surface of Skaneateles Lake at Syracuse. Crystals fed to rotating drum for soln. in regulated amt. of water and then sprayed over surface of water through nozzles by high-pressure pump. Drum operated by storage battery of boat motor. Low-pressure pump feeds water to drum and high-pressure pump driven by boat motor. Sprays cover width of 40–50′, and in application parallel courses about 700′ apart traversed. Wind action depended upon for further distr. Lake, 15 mi. long and ¾ mi. wide, can be treated with 11 tons of copper sulfate in about 16 hr. At Liberty, monohydrated copper sulfate applied as powder with blower. By this method it can be applied over surface of water as boat proceeds and can be driven several hundred ft. to reach shallow areas. During winter months, copper sulfate applied under ice by suspending bag of crystals in propeller stream of outboard motor, also supported over hole. At Newburgh, copper sulfate applied by gasoline-driven blower.

Granular-size material used to apply heavier doses or to control deeper growing organisms and more finely (snow) ground material used for lighter doses or to control organisms growing on or near surface of water. Each of these methods developed in attempt to get away from unsatisfactory results obtained by dragging bags of copper sulfate behind rowboats.—*P.H.E.A.*

Predetermining Effective Dosage of Copper Sulfate in Alga Control. WILLIAM D. MONIE. W. & Sew. Works, **93**:173 ('46). Samples should be collected daily during growth period for micro-organism count to note when dangerous level reached; only then is $CuSO_4$ treatment economical. Growth of different types anticipated from surface-temp. readings. Dosage of $CuSO_4$ can be estd. without regard to surface temp., compn. of water, and, within limits, type and concn. of organism present, by noting amt. of $CuSO_4$ that gives greatest increase in alky. This is done in Nessler tubes with series of sample portions to which equal amts. of phenolphthalein, as required to color a blank, are added. Dosage of $CuSO_4$ giving deepest color selected. If free CO_2 present, all samples treated with phenolphthalein and amt. of weak NaOH soln. required to color blank. This test resembles free CO_2 titration. Tube inversion rack illustrated. Sep. alky. maxima shown when 2 organisms infest supply. Application of $CuSO_4$ from sacks suspended from boat planned according to depth. In deep reservoirs only top 20 ft. considered. Tabulation of consumption of $CuSO_4$ by years shows economy following adoption of test procedure.—*C.A.*

SOFTENING AND IRON REMOVAL

It's No Longer an Experiment. H. V. PEDERSEN. Am. City. **63**:5:86 (May '48). Calcining sludge from lime-soda ash softening plant at Marshalltown, Iowa, now passed beyond experimental stage. High-grade lime recovered and sludge disposal problems eliminated. Waste slurry from settling tanks first fed to Bird centrifuge producing 60% calcium carbonate (40% moisture). Mixed with predried material this cake flash dried at 900°F., then calcined at 1800°F. Quicklime continously removed by screw conveyor to lime slaker. Entire process requires 5 min. from settling tank to slaker. Centrifuge rated at 1200 lb. dry calcium carbonate per hr.; equivalent to 600 lb. lime per hr. Fuel requirements vary between 70 and 80 gal. of oil per ton lime. Electric energy 100 kw. per ton. Because of location of calcining plant 4 hr. of labor required per ton lime. Better layout of plant could reduce labor time by half. Lime produced costs $1.00 per ton less than commercial lime.—*F. J. Maier.*

A Convertible Softening Plant. ANON. Am. City. **63**:1:84 (Jan. '48). Anticipated pop. growth of Sarasota, Fla., probably means eventual abandonment of limited ground water source of very hard water. Present pop. does not warrant cost of 18-mi. transmission main and dam for surface supply at Myakka R. New softening plant designed so that zeolite beds readily convertible to sand filters. Filters now contain 42" zeolite on 12" gravel and are operated at 1.1 gpm./sq.ft. rate. When sand used rate will be 2.0 gpm./sq.ft. Softened water of 17 ppm. hardness mixed with raw water of 120 ppm. hardness to produce delivered water of 100 ppm. hardness. Filtered and chlorinated sea water used for regeneration. For each gal. of water delivered, 1.4 gal. ground water pumped and 0.5 gal. sea water used.—*F. J. Maier.*

Water-Softening Materials of Zeolite Type. III. SHOICHIRO NAGAI & KEIICHI MURAKAMI. J. Soc. Chem. Ind. (Japan) **44**:709 ('41). Water softening and regenerative power of various commercial water softeners and of those prepared by authors were tested by dry and wet methods. Gel-type water softeners prepared from Na silicate, AcOH, and $Al_2(SO_4)_3$ solutions had very good (approximately equal) water softening and recovering powers. They were translucent; molecular composition was $(0.5\text{–}0.6)R_2O \cdot 1.0\, Al_2O_3 \cdot (8.7\text{–}11.4)SiO_2 \cdot (5\text{–}8)H_2O$.—*C.A.*

Improved Device for Removing Precipitated Solids From Water Softening Apparatus. WALTER H. GREEN. U.S. 2,429,315 (Oct. 21, '47). Primarily an improved solids separator of Hughes type.—*C.A.*

Softening of Water. Br. 576,014 (Mar. 14, '46). Process and apparatus for softening water is described. Process involves

passing the water mixed with CaO or CaO and Na_2CO_3 through vessel containing crystalline nuclei, and then passing it through bed of stabilizing material serving to remove free CaO and $CaCO_3$.—*C.A.*

Softening of Water. EDWARD L. STREATFIELD. Brit. 576,019 (Mar. 14, '46). Water, which is previously treated with CaO, or CaO and Na_2CO_3, passed through bed of carbonaceous zeolite. Layers first traversed by water comparatively spent and serve to stabilize it, while layers subsequently traversed by water comparatively fresh and serve to complete removal of permanent hardness. Thus spent and fresh layers form 2 parts of single bed of carbonaceous zeolite.—*C.A.*

Treatment of Water and Aqueous Solutions. M. HAMON. Belg. 452,058 (Sept. '43). Water or soln. (to be softened) added to aq. soln. or suspension of pptg. reagents in presence of granular catalyst held in dense suspension (800 g./l. of useful space of reaction chamber). Part of grains of catalyst, unaccompanied by pptd. sludge, drawn out of reaction chamber and reintroduced in neighborhood of point where water comes in contact with reagents.—*C.A.*

A New Filtering Material for Removing Manganese and Iron From Industrial and Drinking Waters. SZILÁRD PAPP. Magyar Mérnök Építészegylet Közlönye (Hungary) **78**:345 ('44). Special material called "fermago," consisting of oxides of Fe and Mg treated by heat and mixed with disintegrated quartz, oxidizes dissolved Fe or Mn, ppts. colloidal hydroxides, and removes them by filtration. This material produced in grain sizes 0.5–1.5, 1.5–3.0 and 3.0–5.0 mm. or larger. In water high in CO_2, material of smaller grain sizes (thus contg. larger surface) must be used. Treating 1 cu.m. of water in hr. contg. not more than 30 mg./l. free CO_2 and not more than 5 mg./l. Fe requires 300 kg. "fermago" of 1.5–3.0-mm. grain size with total vol. of 210 l. This substance can be regenerated after using for 4–5 yr. by treatment with dil. (5%) HCl.—*C.A.*

Regeneration of Hydrogen-Exchange Materials. Br. 584,481 (Jan. 15, '47). H-exchange materials regenerated in 3 stages, first and second consisting of passing partially exhausted aq. acid solns., which were effluents from previous regeneration, through material until at least 70% and 80–95%, resp., by wt. of absorbed metallic ions, have been removed. In third stage fresh aq. acid passed through material until effluent free from metallic ions. Effluents from second and third stages used as first and second stages, resp., in subsequent regeneration. H-exchange material washed with water before and after regeneration.—*C.A.*

Reducing the Color Throwing of Organic Hydrogen Zeolites. FRANK D. PRAGER. U.S. 2,429,943 (Oct. 28, '47). Color throwing of org. hydrogen zeolites with water of high pH reduced by using 2 hydrogen zeolite-contg. tanks in series. Water passed through tank 1 and then tank 2 until 50% of break-point capac. reached and thereafter through tank 2 then tank 1 to break point.—*C.A.*

ANNUAL REPORTS

Little Rock (Ark.) Munic. Water Works. Annual Report 1947. 3-man board. Pop. of city 109,900; pop. served 139,100. Per capita production 85 gpd., sales 72 gpd.; 24,036 consumers. Income of \$917,621. Fixed assets of \$8,502,359 and cash reserve of \$956,132 are offset by capital liabilities and funded reserves of \$5,806,628. Surface water supply, water shed 43 sq.mi., normal rainfall 48″, normal runoff 14 billion gallons, impounding reservoir 14 billion gallons. A 39″ pipeline 35 mi. long, capacity 25 mgd., delivers water to 92-mil.gal. auxiliary storage reservoir and 15-mgd. filtration plant. Water production avgd. 11.90 mgd., max. 19.40 mgd. Water delivered had total hardness of 18 ppm. Electric pumping station rated capacity 14.25 mgd. Distr. system: 151 mi. of 4 to 24″ mains and 136 mi. of 1 to 3″ mains deliver water to 1297 hydrants and 23,994 meters. About 10 mi. of water mains constructed. Increased filter of 8 mgd. capacity expected available in '49.—*O. R. Elting.*

Denver (Colo.) Annual Report (Year Ending Dec. 31, 1947). Pop. 440,000. Water consumption avgd. 80.40 mgd., max. 178 mgd. Income \$3,669,734; disbursement: operation and maintenance 34%, depreciation 17%, capital expense 39%, invested capital 10%

First cost of plant $44,905,102, depreciated value $32,958,128, cash investment $3,596,941. Capital liabilities $20,068,000. Total services 91,905, active meters 4823; 5066 services added. System consists of 115 mi. of 12″ to 84″ conduits and 883 mi. of 1″ to 48″ mains in the distribution system. 4608 fire hydrants. Source of supply South Platte River 58%, Fraser River 25%, storage 9%, Cherry and Bear Creeks 8%. Filter plants and pumping stations 176 mgd. capacity. Distributing reservoir 99 mil.gal., operating reservoir 10,686 mil.gal., storage reservoir 63,397 mil. gal. $30,000,000 improvement authorized, $23,000,000 bonds, $7,000,000 from surplus. 24-mil.gal. reservoir and 5-mil.gal. reservoir started. 12 mi. of 34″ wood-stave conduit replaced by 30″ concrete pipe.—*O. R. Elting.*

Detroit (Mich.) Dept. of Water Supply. Annual Report (Year Ending June 30, 1947). Four-man Board of Water Comrs. Pop. served 2,376,205; 463,759 services, 99% metered; 29,138 hydrants in city of Detroit only. Water supply: Detroit R., direct pressure (except for 6 elevated tanks with total capac. of 9.5 mil.gal.) through 5241 mi. of mains by 3 pumping stations with total capac. of 1221 mgd. 30-mil.gal. reservoir and booster station under contract. 2 rapid sand filter plants with total rated capacity of 592 mgd. Gross revenue $10,201.316 or $4.16 per capita, $30.29 per account, $1993 per mi. of main, $81.55 per mil.gal. Operating and maintenance expense of $3,969,332 or $31.73 per mil.gal. Capital expense $4,585,285. Net cost of works $131,931,797; bonded debt $58,676,000; value of sinking fund $20,459,897; interest rate 4.10%. Income and expense per 1000 cu.ft. (revenue water basis): revenue $0.776; operating and maintenance $0.283; fixed charges $0.327; net income $0.129. Pumpage avg. 342.711 mgd.; max. 499.2 mgd. Avg. consumption 144 gpd. per capita, or 739 gpd. per service. Salaried employees 551; per diem employees 587. Cost of operation and maintenance of 20-story Water Board Building $1.42 per sq.ft. of rentable area. Water Board occupies seven floors, remainder occupied by various city departments. Sewage disposal system operated under board's jurisdiction.—*O. R. Elting.*

Kalamazoo (Mich.) Water Utility. Annual Report (1947). Pop. 59,753. Established '69. 28 wells, total capacity 11,625 gpm.; storage 8.6 mil.gal.; mains 169 mi.; 1169 hydrants; 15,380 services, 100% metered. Water consumption avg. 9.20 mgd.; max. 14.35 mgd. 14 test wells averaging 190 ft. driven in search for additional supply; 2 wells found suitable for water production; their development is expected to add 1.15 mgd. to system.—*O. R. Elting.*

St. Louis (Mo.) Water Division. Annual Report (April 7, 1947). Water works acquired in 1835. Pop. 850,000, daily consumption 155.4 mil.gal. or 183 gal. per capita. Distribution system of 1256 mi. serves 157,027 services (9.4% metered) and 15,240 public and private fire hydrants. Gross revenue from sale of water $4,310,431 less $64,917 commission paid collector, refunds $2,802, net revenue $4,242,712. Operation and maintenance $2,477,072. Excess of total receipts over total expenditures $1,137,218, revenue $76.71 per mil.gal. consumed. Cost of plant $52,874,562. Bonds outstanding $424,000. Supply from Mississippi River. Two plants combined capacity 240 mgd. Pump capacity to plant 560 mgd., to city 340 mgd., distribution storage 264 mil.gal. River water: turbidity, 1.520; hardness, 197; color, 20 ppm. Purified water: turbidity, 0.09; hardness, 107; color, 9 ppm. Ten-yr. program of metering recommended. Improvements costing $14,000,000 recommended with construction delayed until labor and materials more plentiful. Maximum day of 240 mgd. estimated in '58.—*O. R. Elting.*

North Jersey District Water Supply Commission. Wanaque (N.J.) Water Supply System (1946–47). 5-man board operates system supplying 8 municipalities. System comprises 2310-acre reservoir of 29,510 mil.gal. on 94-sq.mi. watershed and aqueduct 21 mi. long (14 mi. twin 74″ mains, 2 mi. 7′ tunnel, 5 mi. single 74″ main). 5 pumps, 126 mgd. total capacity for operation with low water in reservoir. System in operation since '30. Water consumption 91.87 mgd. '46, 89.92 mgd. '47. Max. 113.65, '46; 109.4, '47. Chlorine treatment 1.0 ppm. Lime 41 lb. per mil.gal. Ammonia 0.5 lb. per mil.gal. Rainfall '46, 42.56″; '47, 50.85″, 26-yr. average 47.58″. Request to divert maximum of 100 mgd. from Ramapo River with average of 25 mgd. denied by state for technical reasons.—*O. R. Elting.*

Ohio Water Resources Board. Annual Report (1947). State board to collect and interpret data relative to waters in state, cooperate with other agencies in planning and establishment of water conservation practices and prescribe rules for drilling and operation of wells. '47 progress: inventory of water resources —193 stream-gaging stations and 120 well-gaging stations maintained, chemical analysis at 6 stations with spot tests at 75 others. Field geologic investigation carried on by drilling of test wells in 5 counties. Studies on stream flow and reservoir sedimentation made. All data compiled and numerous reports published. Investigation of underground waters of great importance, rules for reporting well drilling, plugging, etc., established.—*O. R. Elting.*

Greenville (S.C.) City Water Works. Auditor's Report (Year Ending July 31, 1947). Net profit from operation $291,947, compared with $268,684 for '46 and $232,792 for '45. Of this sum $173,000 applied to capital charges; $67,562 to addns. to plant. Plant and equip. $5,168,187. Total assets $5,776,-637. Surplus (excess of assets over liabilities) $2,690,729.—*O. R. Elting.*

Newport News (Va.) Water Works Com. Financial Report (1947). Depreciated value of plant $7,565,221; current assets $1,055,267; deferred charges $607; total assets $8,621,096. Outstanding bonds $2,024,000; other liabilities $467,055; surplus $6,130,042. Water sales $878,169; other income $117,262; operating expense $534,657; interest $101,-344; other expense $12,159; net income $347,272.—*O. R. Elting.*

Portsmouth (Va.) Annual Report (1947). Consumption 9.5 mgd. 292 mi. of mains, 1018 hydrants, 22,454 meters. Surface water supply. Watershed 50 sq.mi., reservoir area 850 acres, storage 2.45 bil.gal. Treatment plant 18 mgd. Income $757,000, expense $712,000. Depreciated plant $4,950,000. Net bonded debt $214,000. Expansion and rehabilitation costing $765,000 recommended. —*O. R. Elting.*

Aberdeen (Wash.) Water Dept. Financial Report (1947). Gross income $247,502; operating expense $162,924; miscellaneous revenue $11,044; operating income $95,624; interest, taxes, etc. $55,965; profit $9,786. Assets: fixed $3,178,719; investments, real estate and buildings $143,829; other $180,205; total $3,502,754. Liabilities: bonds $636,000, special municipal tax revenue $432,950; current $38,188; reserves $1,145,822; surplus $1,249,794.—*O. R. Elting.*

Seattle (Wash.) Water Dept. Annual Report (Year Ending Dec. 31, 1947). Estimated population served 564,598. Estimated consumption 76.73 mgd. Peak 166 mgd. Supply and distribution mains total 1195 mi., serving 112,133 metered services and 10,793 hydrants. Gross operating revenue $3,479,-061; nonoperating revenue $95,864; operating expense $922,328; depreciation $712,138; interest on bonds $122,717; amortization of bond discount $6,172; taxes $1,121,717, leaving net income of $689,792 added to surplus account; total surplus $14,526,158. Depreciated net value of resources $24,844,066. Outstanding bonds $2,666,000. Cost of water delivered per 100 cu.ft.: operation, maintenance and depreciation $0.0438; total $0.0772. Tap water: total hardness 23.8 ppm.; pH 7.15. Cl. 2.2 ppm. Increased cost of water delivered due to higher material cost and increased labor cost and manpower. Contracts entered into for improvements totaling $1,937,211. Proposed plant improvement costing $600,000 in '48 from reserve funds.—*O. R. Elting.*

Green Bay (Wis.) Water Dept. Annual Report (1947). Five-man Board of Commissioners. Purchase price $999,750. Bonds outstanding $588,000. Mains 139 miles, 11,647 metered services, 797 hydrants. Average consumption 4.68 mgd., 93.5 gpd. per capita, 85.5% water sold. Pumpage was greatest in history. Water obtained from 7 wells. One pump lowered to prevent breaking of suction during peak pumping. New 24″ well completed but not put in service. Engineering survey of available supply to be made.—*O. R. Elting.*

The Water Supply of Sydney (Australia). ANON. Wtr. & Wtr. Eng. (Br.) **50**:463 (Sept. '47). Water supply of Sydney drawn from 3 rivers, Nepean, Woronora, and Warragamba and stored in 6 large reservoirs. Conveyed 40 mi. by tunnel to Prospect Res. Water from Woronora reservoir gravitates through 16 mi. of 48″ mains to Penshurst service reservoirs. Full exploitation of Warragamba R. Catchment, largest project of its kind in

Australia, will provide for pop. several times larger than at present served. Dam, now under constr., will be over 300′ high. Water mains in '46 had mileage of 4656.8. There are 92 service reservoirs with total capac. of 537.6 mil.gal. (Imp.), 6 storage reservoirs with total capac. of 125,144 mil.gal. (Imp.), and 36 pumping stations. Water consumed in year '45–'46 44,437 mil.gal. (Imp.), giving avg. consumption per capita of 74.8 mgd. (Imp.). Water rate 9.25d per pound of annual ratable value.—*H. E. Babbitt.*

Metropolitan Water Board (Gt.Br.). 44th Annual Report (Year Ending Mar. 31, 1947). Wtr. & Wtr. Eng. (Br.) **50**:542 (Nov. '47). First section deals with constitution of board, its committees, staff, etc.; second with financial matters; third with sources of supply, statistics, and general information with regard to water supply; and fourth with miscellaneous matters. Numerous appendixes contain data on water abstracted from Thames and Lea Rivers, from riverside gravel beds, and from wells. Daily avg. Thames flow 1853.2 mil.gal. (Imp.). Total vol. supplied by board, 118,796 mil.gal. (Imp.). Board contemplates establishment of one authority for area comprising 2700 sq.mi. from Baldock in north to Horley in south, and from Maidenhead in west to Gravesend in east. Of 12,488 samples of water pumped into supply 98.7% contained no *Esch. coli* in 100 ml. Algal growths in reservoirs prevented by small doses of copper sulfate and chlorine. Flooding of Lea Bridge water works during March put whole of works out of action for 9 days. Est. pop. of 350,000 supplied by tank wagons and 14 mil. gal. (Imp.) delivered in this way in 10 days. Total expenditure on revenue acct. was £7,715,920 of which £7,533,240 was to be raised by water charges. Consent of Ministry of Health has been obtained for raising 8.5% existing domestic rate to 9% of net annual value of premises supplied; to increase metered supply rates by ½d per 1000 gal (Imp.); to increase meter rentals 33⅓%; and to add 25% to remaining charges for supplies afforded otherwise than by measure.—*H. E. Babbitt.*

Baghdad District (Iraq) Water Board. Annual Report (Year Ending Mar. 31, 1946). Wtr. & Wtr. Eng. (Br.) **50**:509 (Oct. '47). Water supply pumped from R. Tigris by 3 pumping stations on left bank and 1 on right bank. New pumps installed at Karrada filtration works increasing capac. to 0.5 mgd. (Imp.). No extension of plant possible during war years. Sarrafiya extension ready in latter half of '46 and meanwhile abnormal growth of demand for water continued. For past 2 years summer demand has surpassed supply capac. When supplies of water meters obtainable at reasonable prices they will be needed in garden suburbs to restrict waste of filtered water. Cast-iron and asbestos-cement mains gave no special trouble. Satisfactory type of service connection has not been found. Neither galvanized iron, asphalted steel nor copper resist for long attack of corrosive soil. Extension of mains limited by shortage of pipes and labor. Extensions totaled 11,682 m. bringing total length to 390.4 km. High-pressure pumps and motors were in England, awaiting shipment. Work in hand provided for 3 new pressure mains to deliver filtered water to 3 dist. balancing tanks. New plant at Sarrafiya will use chlorine obtained by electrolysis of salt. Regular and frequent examn. of water carried out in govt. lab. Results have been excellent. Nothwithstanding greatly increased operating costs, board has maintd. water rates at prewar levels, except for 10% increase in meter rates. Heaviest demand for capital funds in immediate future appears to be that of garden supply systems.—*H. E. Babbitt.*

The Water Supply of Auckland, New Zealand. Anon. Wtr. & Wtr. Eng. (Br.) **50**:464 (Sept. '47). Total quant. of water supplied for yr. ending Mar. 31, '47, 5,460 mil.gal. (Imp.) or 66.28 gpd. per capita. Reduction in consumption below previous year attributed to abundant and well-distributed rainfall. Further progress made on constr. of Lower Nihotupu Dam. Pumping plant and rising main to Mackie's Rest nearly completed. 30″ main from Titirangi completed as far as Kimberley Rd., Epsom. Erection of 6 mil. gal. service reservoir on Mt. Albert seriously delayed by shortage of reinforcing steel and labor. Reticulation work consisted mainly of small extensions for new dwellings. Total length of mains owned by city, including concrete conduit and lined tunnel, now 562 mi., 7 chains.—*H. E. Babbitt.*

Rand (Un. S. Afr.) Water Board. Annual Report (Year Ending Mar. 31, 1947). Board

supplies water in bulk to Transvaal Chamber of Mines, South African Railways Administration and 12 municipalities and villages covering area of 3980 sq.mi. with pop. of 724,000 Europeans and 1,249,000 non-Europeans. Average 69.54 mgd.; '45 and '46 averaged 63.60 and 66.40 mgd. Municipal areas 623 sq.mi. Population: European, 640,000; non-European, 910,000. Average of 35.6 mgd. Remainder to gold mines and railway plus 2.3 mgd. to minor consumers. Total average cost of water in bulk was 4.0d per 1000 gal., divided thus: pumping 1.5d, maintenance 0.9d, purification 0.8d, other 0.8d. Fixed charges and betterments 2.0d per 1000 gal. Source of supply is diversion rights to 215 mgd. from Vaal R. and 10 mgd. from various boreholes and wells. 29.225 mgd. from the river have been disposed of to industrial users. Rainfall in Johannesburg was 35.32". 58-yr. average 33.51". Evaporation at Barrage 63.80". 14 yr. average 57.00". Board's pipelines total 428 mi. with 16.38 mil.gal. storage at pumping station and 114.88 mil.gal. at various high points. System extends 36 mi. from Vaal River at Bereeniging to Central Rand, and 80 mi. along Witwatersrand from Libanon on the west to Nigel on the east. Maximum pressure on mains 550 psi. Project to increase potable supply 20 mgd. to give a total of 90 mgd. is expected to be completed by end of '47. Estimated cost £2,335,000, 21% over 1941 estimate. Second 20-mgd. project has been approved. Estimated cost £1,793,000. Board employs 348 Europeans and 1412 natives. Cost of plant to date approx. £12,680,000. Outstanding indebtedness £6,717,000, less redemption fund of £2,572,000. —*O. R. Elting.*